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(54) AUTOMATED LOADING OF DELIVERY VEHICLES

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See application file for complete search history.

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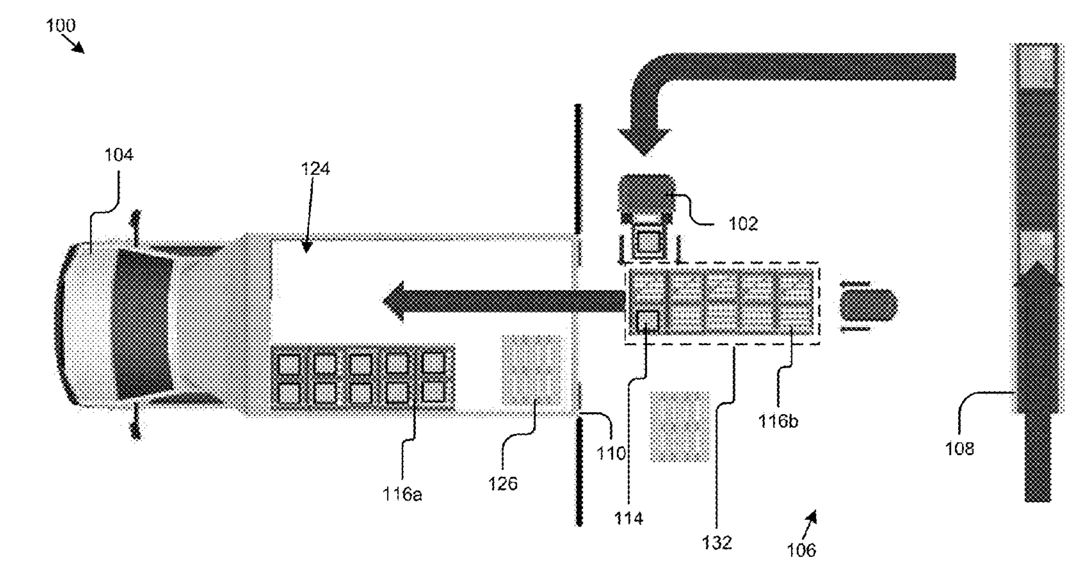
(57) **ABSTRACT**

A system and method for automated loading of delivery vehicles using automated guided vehicles ("AGV"s) is described. In an example implementation, a loading coordination engine may assign a location on a mobile cart to an item and generate a task list including instructions to a first and a second AGV to position the item on the mobile cart based on the assigned location and to transport the mobile cart into a delivery vehicle. The first AGV may transport the item from an item loading area to a point proximate to the assigned location on the mobile cart and place the item at the assigned location based on the task list. The second AGV may transport the mobile cart from a cart loading zone into the delivery vehicle based on the task list and, in some instances, secure the mobile cart to the delivery vehicle based on the task list.

25 Claims, 13 Drawing Sheets



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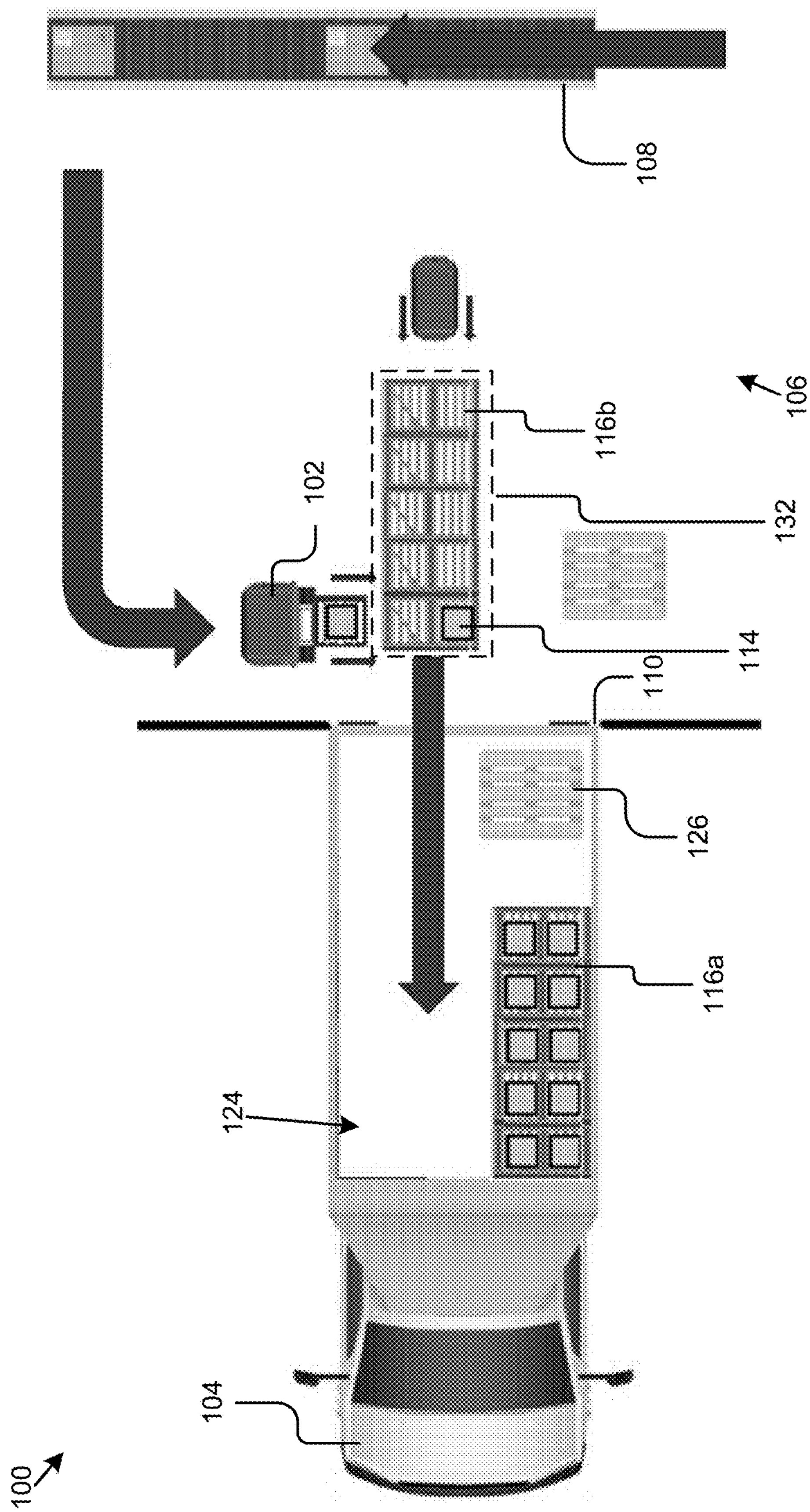

Figure 1

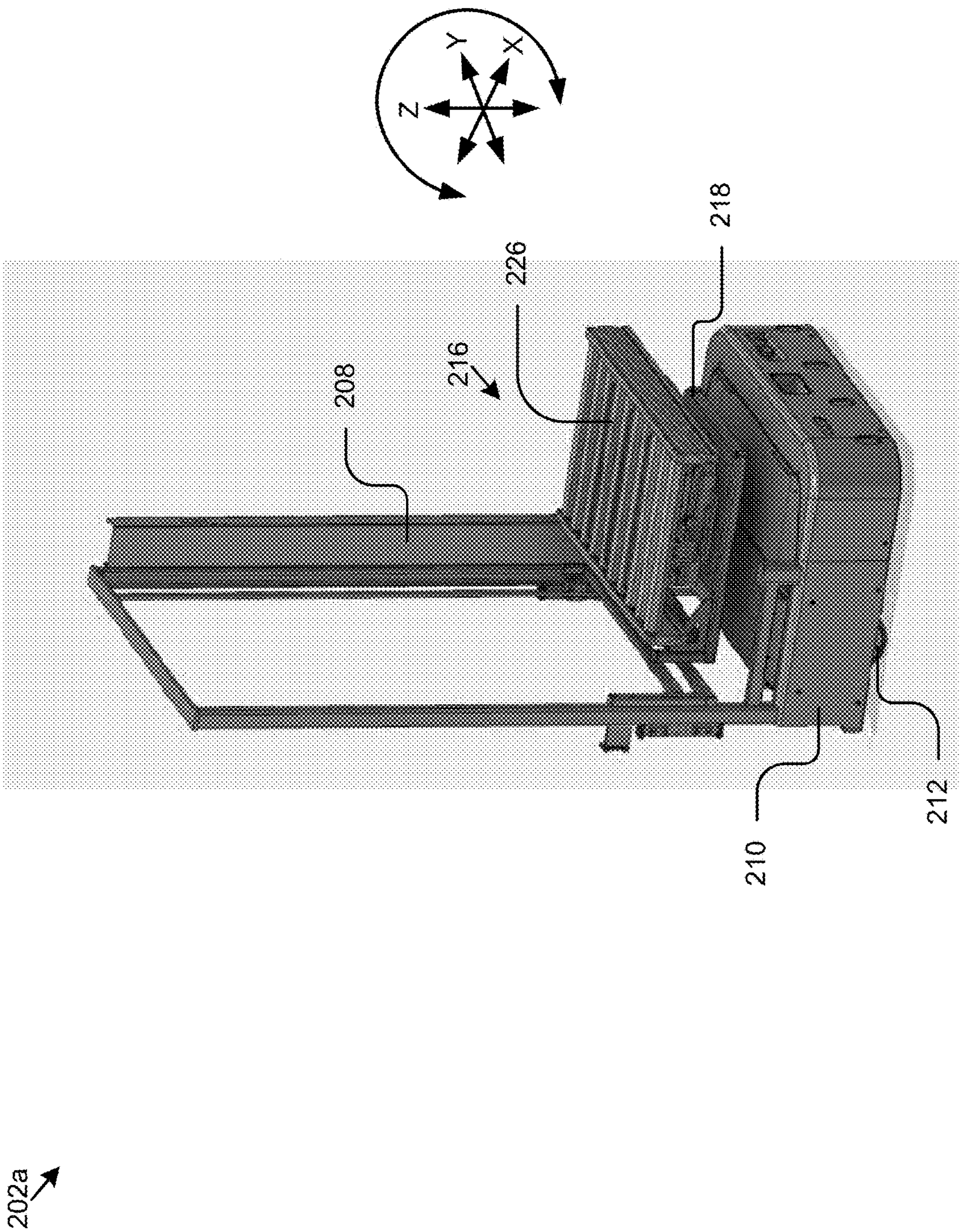

Figure 2A

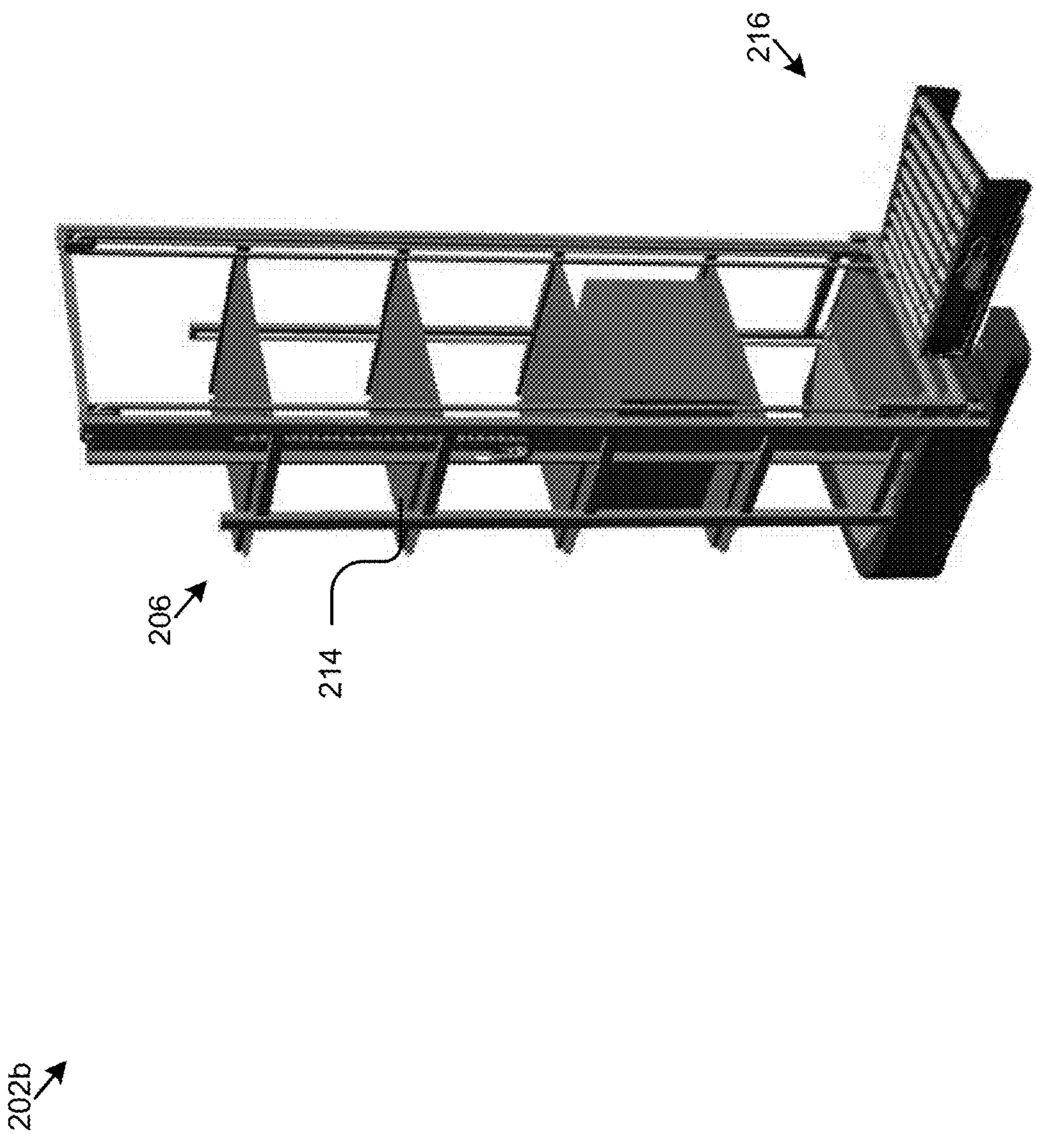

Figure 2B

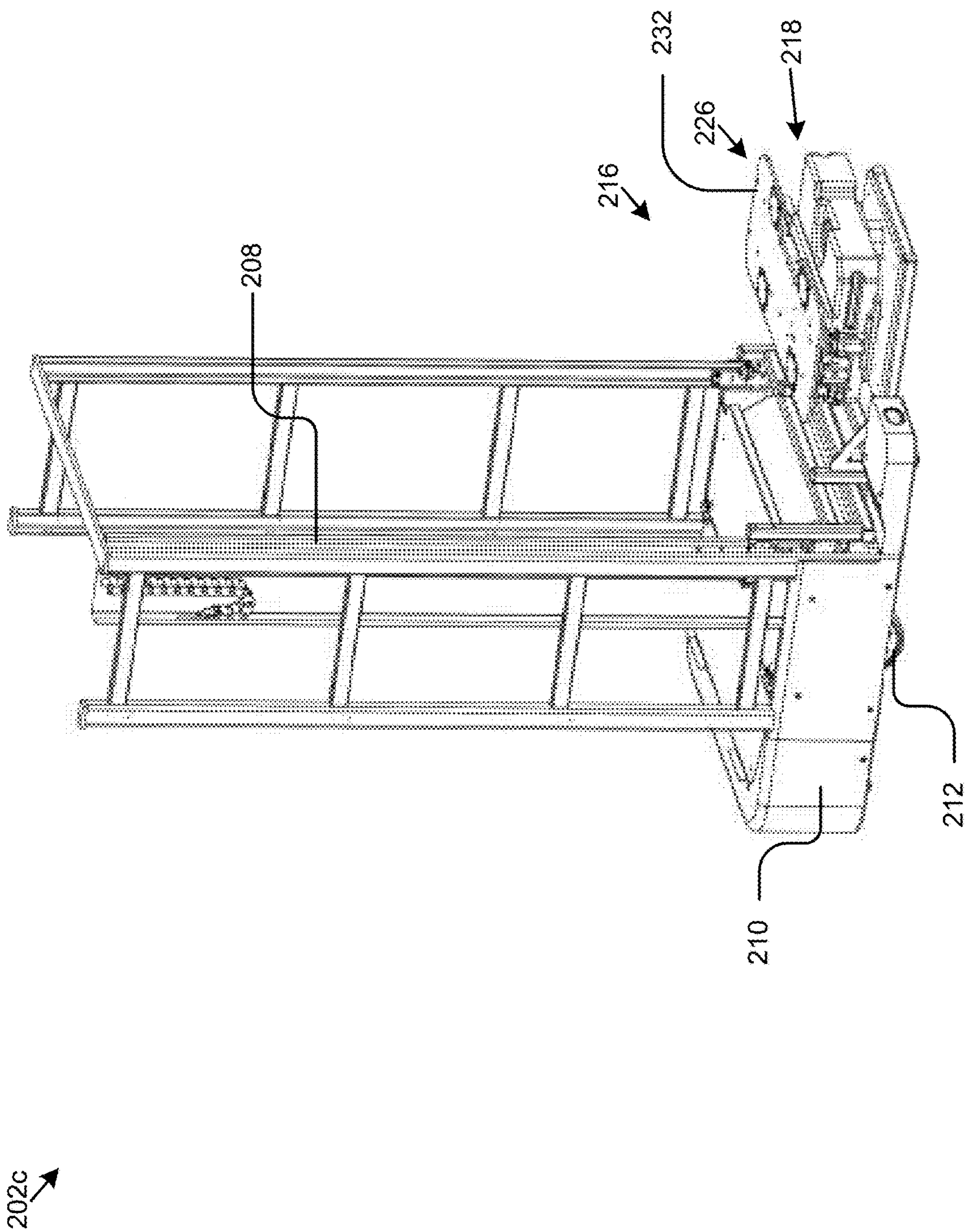

Figure 2C

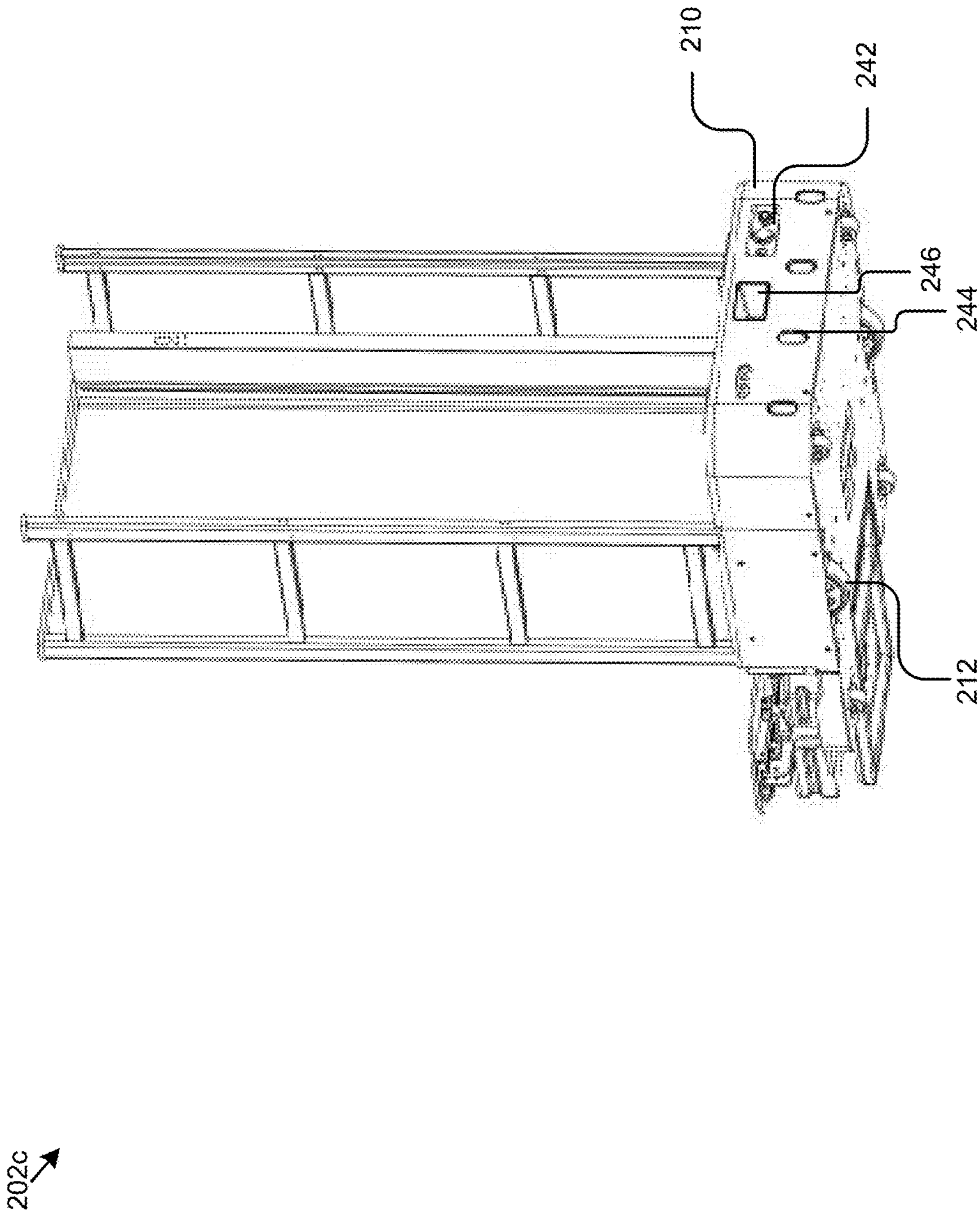

Figure 2D

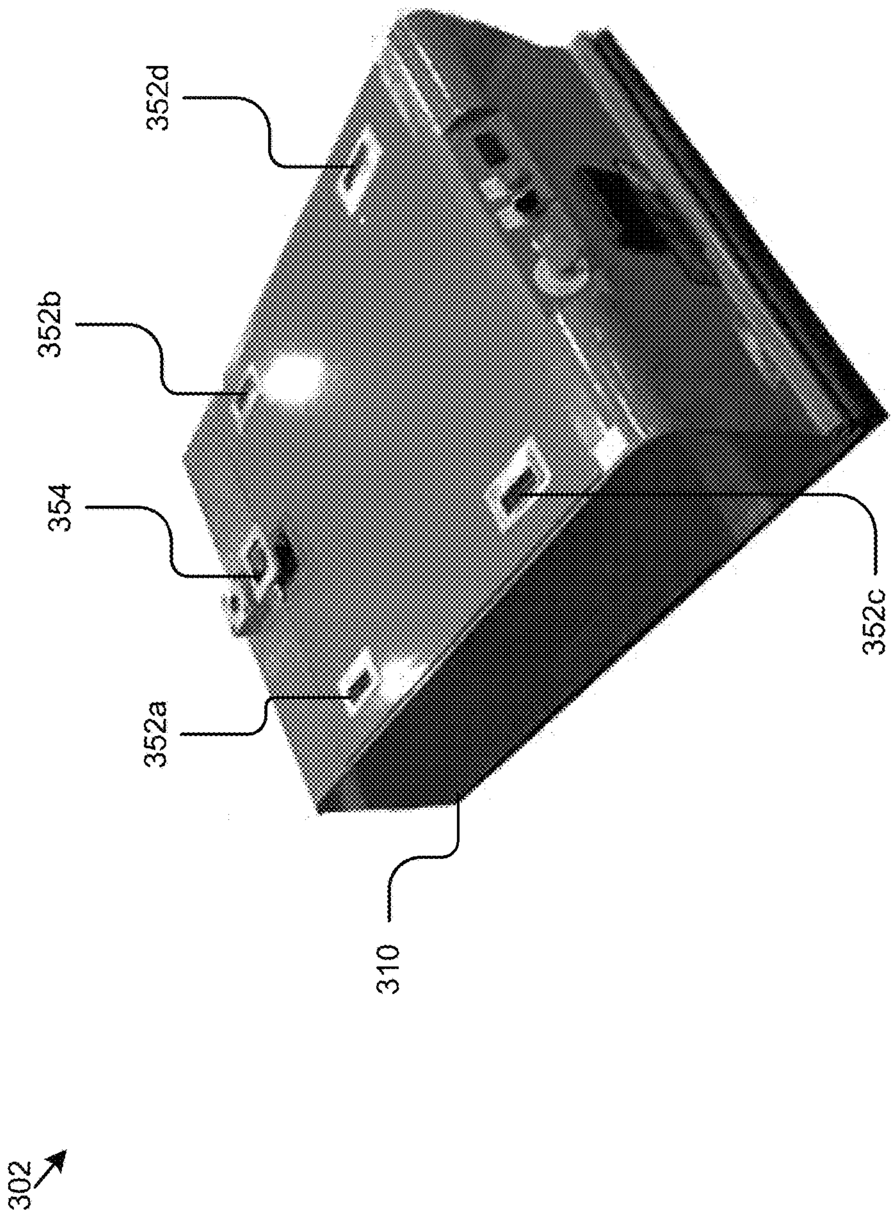

Figure 3

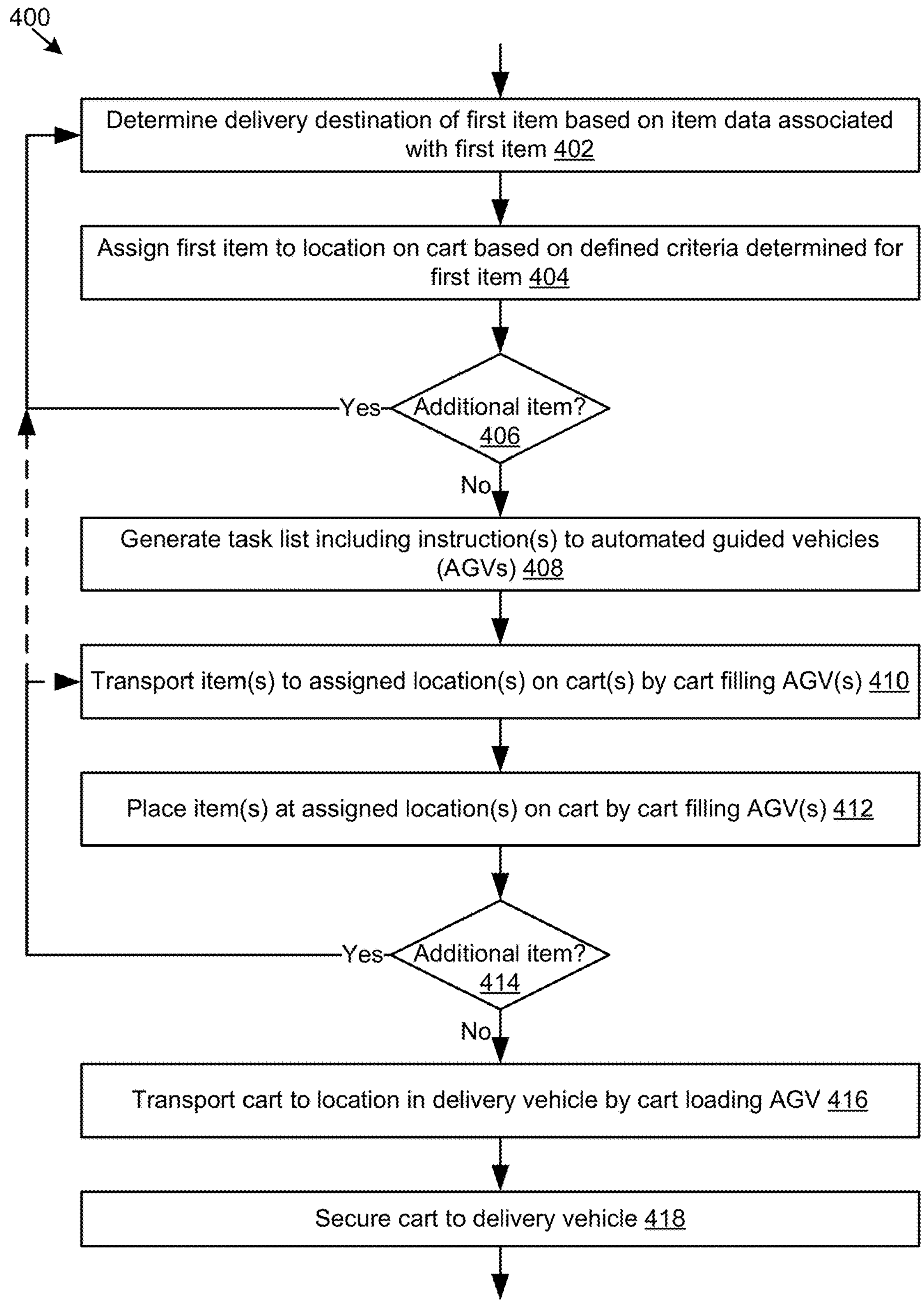
400
Determine delivery destination of first item based on item data associated with first item 402
Assign first item to location on cart based on defined criteria determined for first item 404
Additional item? 406
Yes
No
Generate task list including instruction(s) to automated guided vehicles (AGVs) 408
Transport item(s) to assigned location(s) on cart(s) by cart filling AGV(s) 410
Place item(s) at assigned location(s) on cart by cart filling AGV(s) 412
Additional item? 414
Yes
No
Transport cart to location in delivery vehicle by cart loading AGV 416
Secure cart to delivery vehicle 418

Figure 4

500

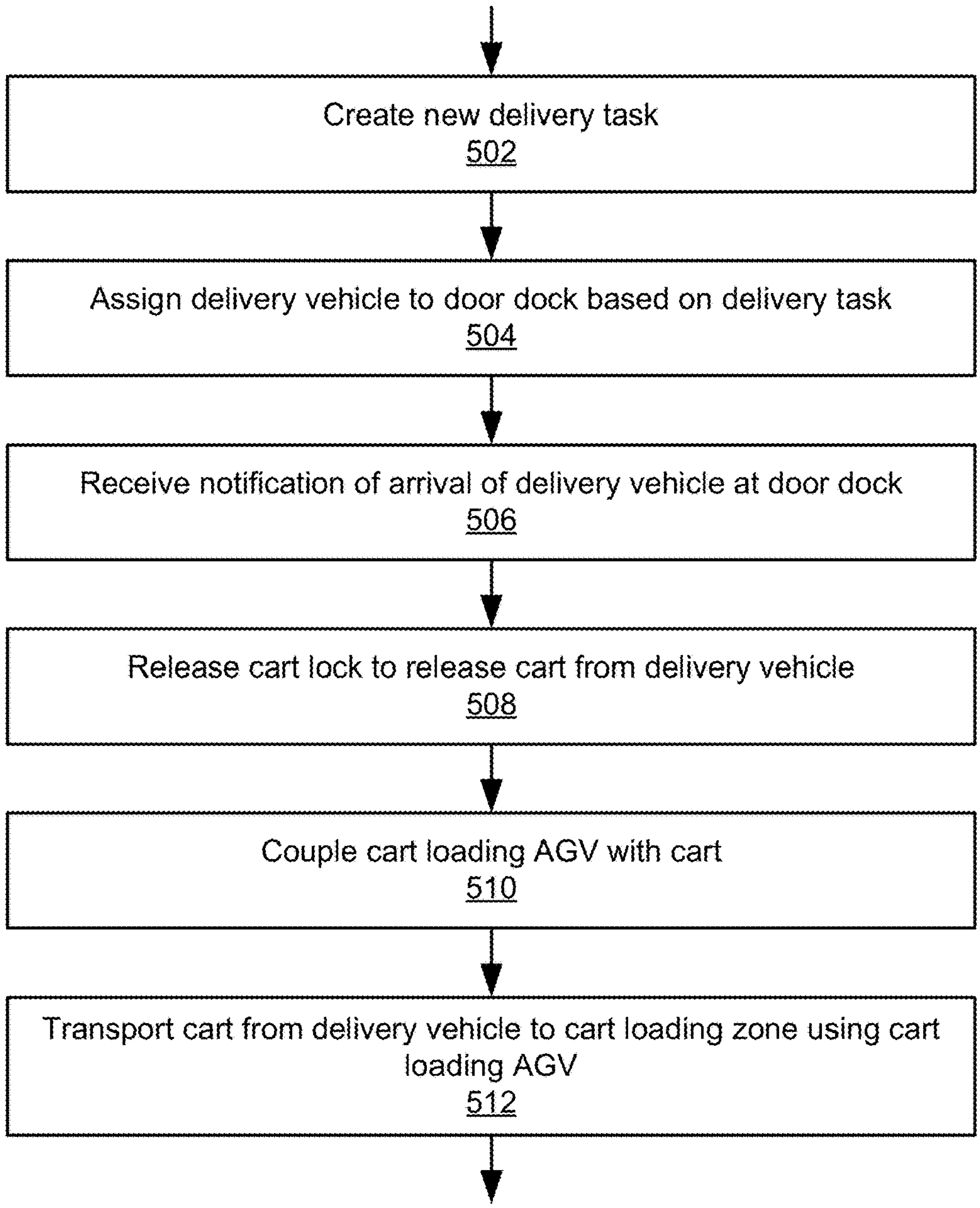
Create new delivery task
502
Assign delivery vehicle to door dock based on delivery task
504
Receive notification of arrival of delivery vehicle at door dock
506
Release cart lock to release cart from delivery vehicle
508
Couple cart loading AGV with cart
510
Transport cart from delivery vehicle to cart loading zone using cart loading AGV
512

Figure 5

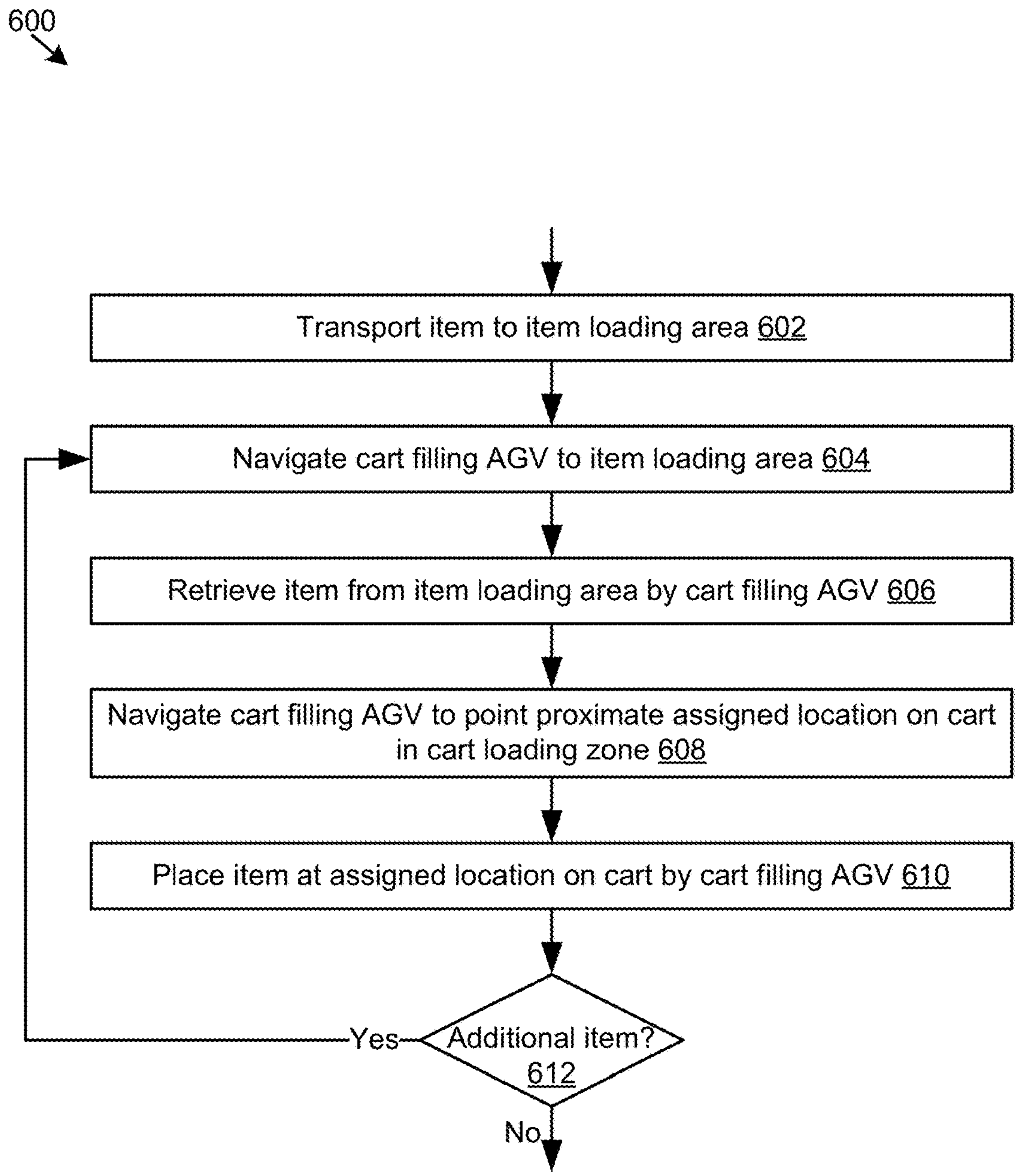
600
Transport item to item loading area 602
Navigate cart filling AGV to item loading area 604
Retrieve item from item loading area by cart filling AGV 606
Navigate cart filling AGV to point proximate assigned location on cart in cart loading zone 608
Place item at assigned location on cart by cart filling AGV 610
Additional item? 612
Yes
No

Figure 6A

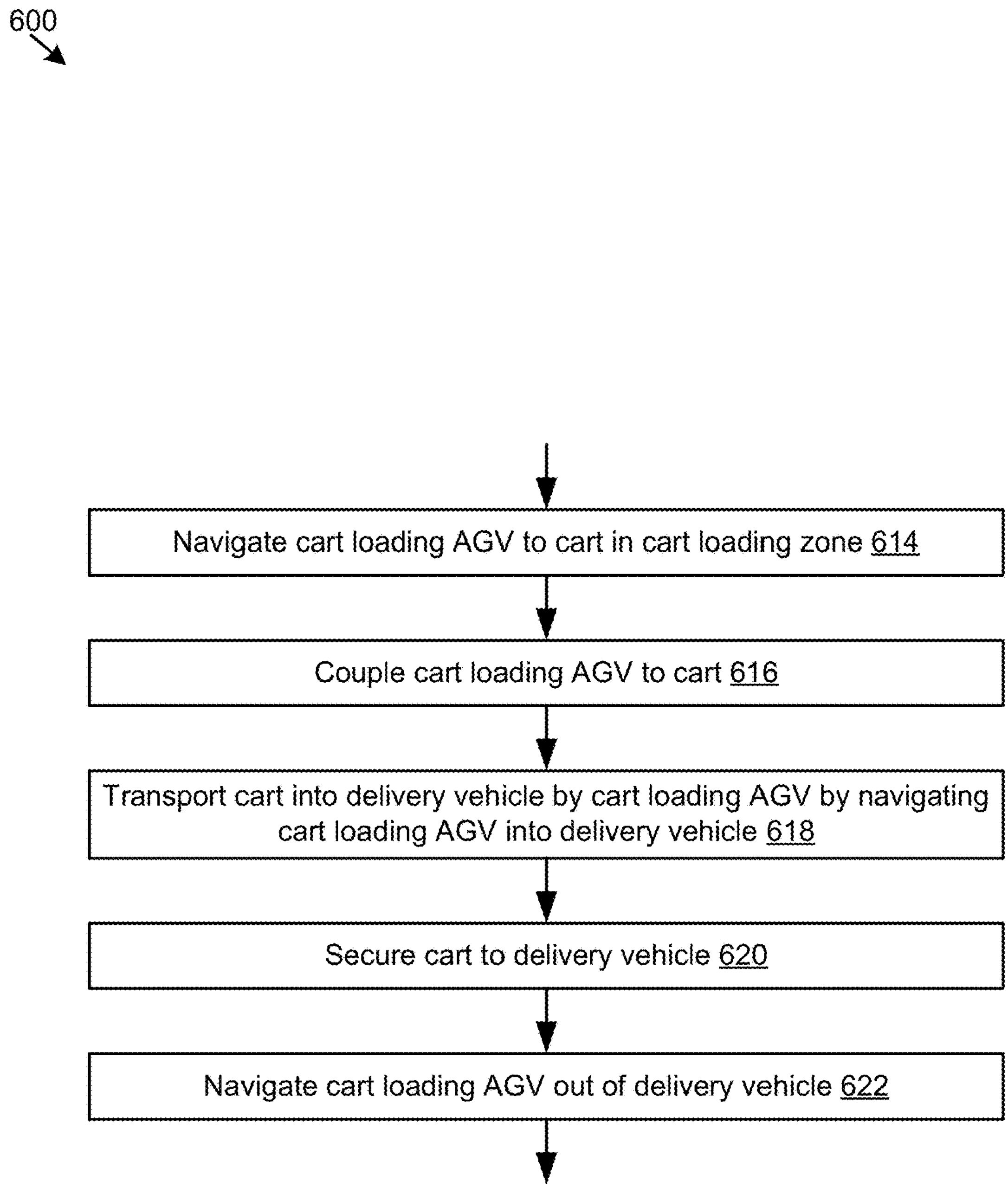
600
Navigate cart loading AGV to cart in cart loading zone 614
Couple cart loading AGV to cart 616
Transport cart into delivery vehicle by cart loading AGV by navigating cart loading AGV into delivery vehicle 618
Secure cart to delivery vehicle 620
Navigate cart loading AGV out of delivery vehicle 622

Figure 6B

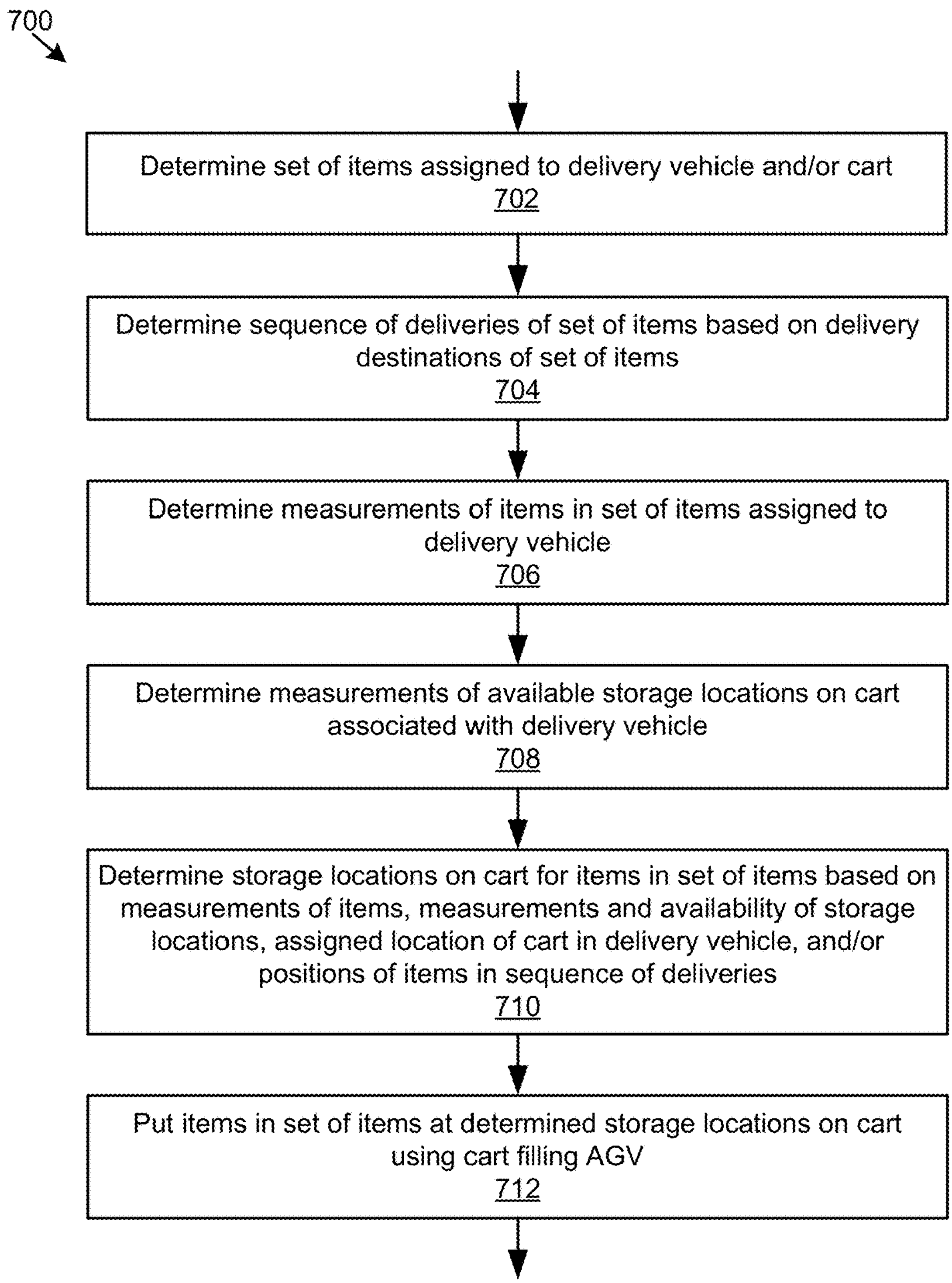
700
Determine set of items assigned to delivery vehicle and/or cart
702
Determine sequence of deliveries of set of items based on delivery destinations of set of items
704
Determine measurements of items in set of items assigned to delivery vehicle
706
Determine measurements of available storage locations on cart associated with delivery vehicle
708
Determine storage locations on cart for items in set of items based on measurements of items, measurements and availability of storage locations, assigned location of cart in delivery vehicle, and/or positions of items in sequence of deliveries
710
Put items in set of items at determined storage locations on cart using cart filling AGV
712

Figure 7

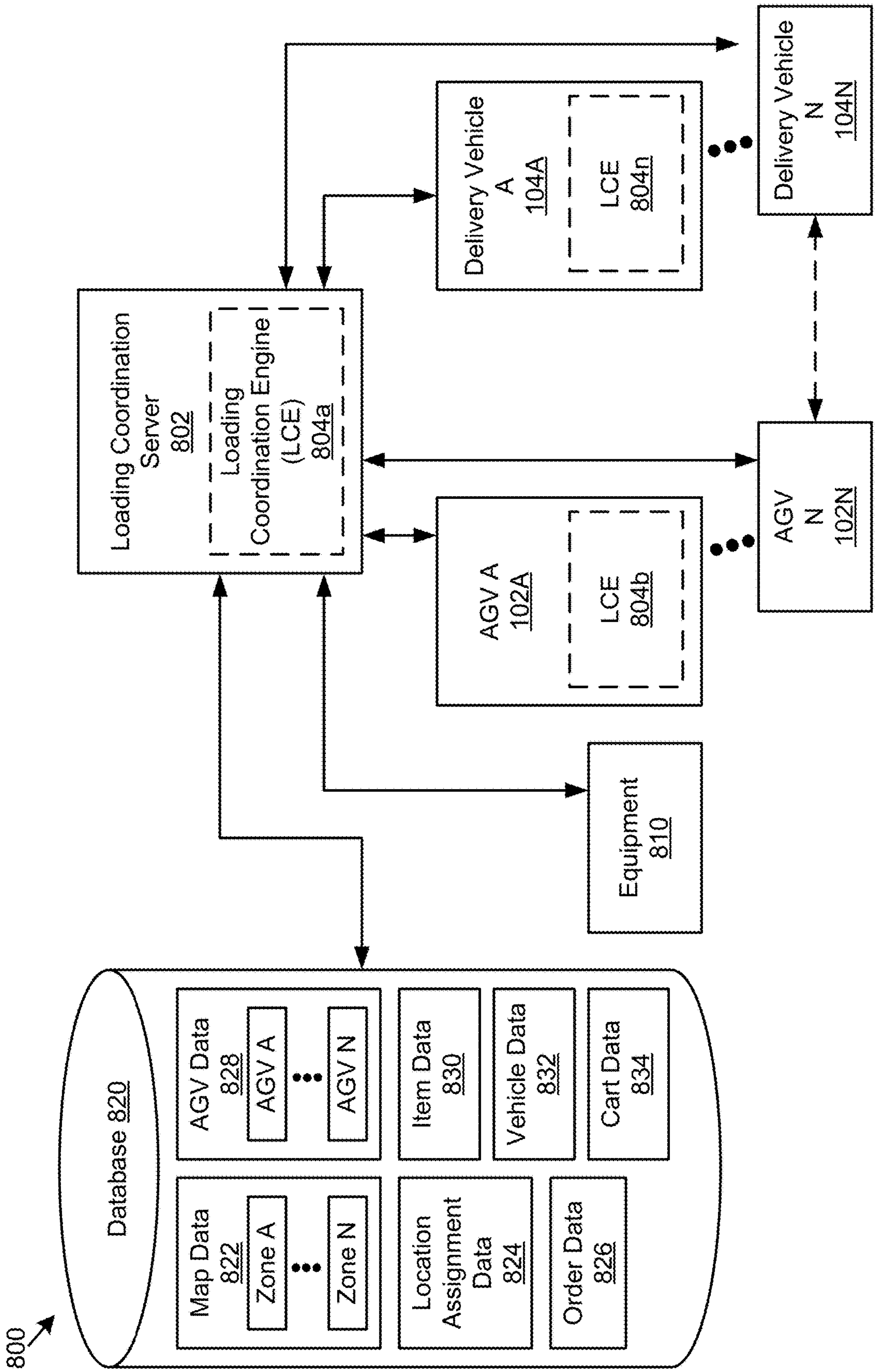
800
Loading Coordination Server
802
Loading Coordination Engine (LCE)
804a
Delivery Vehicle
A
104A
LCE
804n
Delivery Vehicle
N
104N
AGV A
102A
LCE
804b
AGV
N
102N
Equipment
810
Database 820
Map Data
822
Zone A
Zone N
AGV Data
828
AGV A
AGV N
Location Assignment Data
824
Item Data
830
Vehicle Data
832
Order Data
826
Cart Data
834

Figure 8

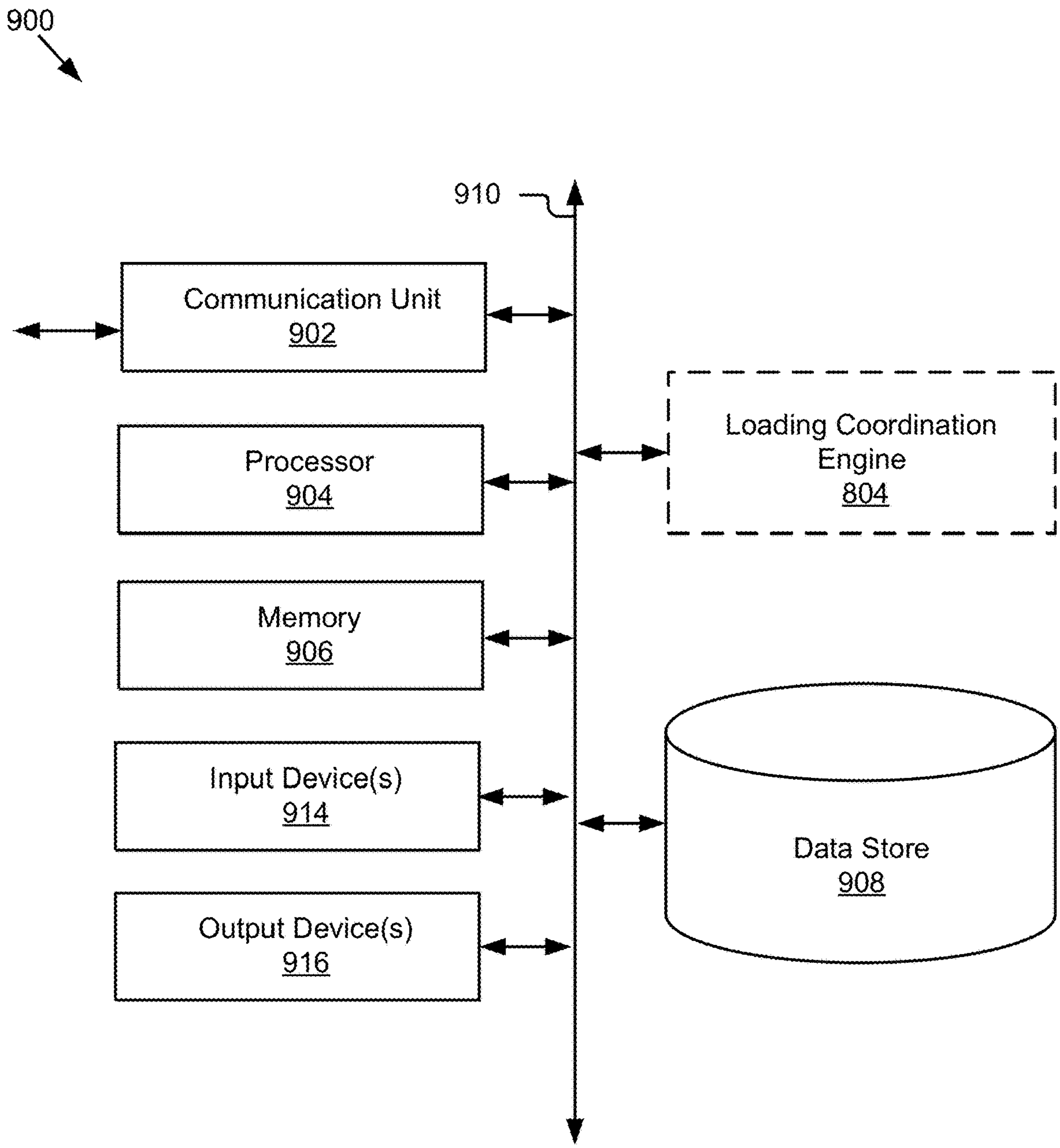
900
910
Communication Unit
902
Processor
904
Memory
906
Input Device(s)
914
Output Device(s)
916
Loading Coordination Engine
804
Data Store
908

Figure 9

AUTOMATED LOADING OF DELIVERY VEHICLES

BACKGROUND

This application relates to automated preparation of delivery vehicles. For example and not limitation, this application relates to coordinating automated guided vehicles load items onto mobile carts and into delivery vehicles.

A delivery vehicle may receive, transport, and deliver tens, hundreds, or more orders containing numerous individual items, which may be loaded from fulfillment centers, warehouses, stores, or other facilities. Some current delivery loading systems use hand trucks or dollies, which are manually loaded with boxes or other items, pulled or pushed by a human into a delivery truck, and then manually unloaded onto shelves in the delivery truck. However, when performing such tasks, humans quickly become physically and mentally tired leading them to work inefficiently, commit errors, and require breaks or work at a slower pace. Further, these solutions require sufficient space within the delivery vehicle for a human to move around, carry items, and, potentially, drag a hand truck, which wastes space in the delivery vehicle.

Some delivery vehicle loading solutions use forklifts to move entire pallets of items, however these solutions are not practical when fulfilling many orders that include, for instance, only a few items while a pallet may include tens or hundreds of items. Additionally, traditional forklifts are not able to navigate within or adjacent to delivery vehicles, because traditional forklifts require substantial space to manipulate a pallet.

Further, tracking which items are loaded onto the delivery vehicle, in what order the items are loaded, or where the items are placed in the delivery vehicle is typically done with pen and paper or not done at all. These solutions require a human to decide how to load the items into the delivery vehicle (e.g., onto which shelves a particular item should be placed), manually load the items, and then update the checklist. However, humans may forget to update the checklist or may place items in a delivery vehicle in inefficient locations, thereby reducing storage and delivery efficiency.

Accordingly, improved delivery vehicle preparation solutions are desirable.

SUMMARY

The subject matter described in this disclosure overcomes at least the deficiencies and limitations described in the Background.

According to one innovative aspect of the subject matter described in this disclosure, the technology may include a first automated guided vehicle (AGV); a second AGV; a delivery vehicle; and a computing system including one or more processors and a memory storing instructions that, when executed by the one or more processors, cause the system to: assign a location on a mobile cart to an item; generate a task list including a first instruction to the first AGV to position the item on the mobile cart based on the assigned location and a second instruction to the second AGV to transport the mobile cart into the delivery vehicle; transport, by the first AGV, the item from an item loading area to a point proximate to the assigned location on the mobile cart; place, by the first AGV, the item at the assigned location based on the task list; transport, by the second AGV, the mobile cart from a cart loading zone into the delivery vehicle based on the task list; and secure the mobile cart to the delivery vehicle.

Implementations may include one or more of the following features. The system where the instructions further cause the system to generate a delivery task, assign the delivery vehicle to a door dock at a loading facility based on the delivery task, and transport the mobile cart from the delivery vehicle to the cart loading zone associated with the door dock using the second AGV, the cart loading zone being determined based on the assignment of the door dock. The system where the instructions further cause the system to receive a notification message indicating arrival of the delivery vehicle at the door dock, transmit an instruction to release a cart lock, the cart lock configured to secure the mobile cart to the delivery vehicle, couple the second AGV with the mobile cart, and transport the mobile cart from the delivery vehicle to the cart loading zone using the second AGV. The system where transporting, by the first AGV, the item from the item loading area to the point proximate to the assigned location on the mobile cart includes navigating the first AGV to the item loading area, retrieving the item from the item loading area by the first AGV, determining the point proximate to the assigned location on the mobile cart based on a location of the mobile cart, the assigned location, and a range of motion of an item handling mechanism of the first AGV, and navigating the first AGV to the point proximate to the assigned location on the mobile cart in the cart loading zone. The system where placing, by the first AGV, the item at the assigned location based on the task list includes articulating an item handling mechanism of the first AGV to a height matching a shelf of the mobile cart at which the assigned location is located, and transferring the item from the item handling mechanism to the shelf at the assigned location. The system where transporting, by the second AGV, the mobile cart from the cart loading zone into the delivery vehicle based on the task list includes navigating the second AGV to the cart loading zone, coupling the second AGV with the mobile cart in the cart loading zone, and navigating the second AGV with the mobile cart using a guidance system of the second AGV including applying motive force to the mobile cart by the second AGV to transport the mobile cart into the delivery vehicle. The system where securing the mobile cart to the delivery vehicle includes actuating a cart lock to secure the mobile cart to the delivery vehicle in response to the second AGV transporting the mobile cart to a designated location in the delivery vehicle. The system where the first AGV includes a first drive unit that provides motive force to the first AGV, a first guidance system that locates the first AGV in an operating environment, and an item handling mechanism adapted to move items. The system where the second AGV includes a second drive unit that provides motive force to the second AGV, a second guidance system that locates the second AGV in the operating environment, and a cart coupling mechanism that couples the second AGV with the mobile cart. The system where the instructions further cause the system to capture a label of the item using a scanner communicatively coupled with the computing system, determine a delivery destination based on the captured label on the item, and assign the item to the location on the mobile cart based on the delivery destination of the item. The system where the instructions further cause the system to assign the item to a door dock associated with the delivery vehicle based on a delivery destination of the item, and instruct a conveyor mechanism to transport the item to the door dock associated with the delivery vehicle. The system

where assigning the item to the location on the mobile cart includes determining one or more measurements of the item, determining one or more measurements of available storage locations on the mobile cart, determining a position of a delivery of the item in a sequence of deliveries of a set of items assigned to the delivery vehicle, and determining the assigned location of the item based on the one or more measurements of the item, the one or more measurements of the available storage locations on the mobile cart, and the position of the delivery of the item in the sequence of deliveries.

In general, another innovative aspect may include one or more AGVs that may include: a body; a drive unit coupled with the body and providing motive force to the body; a guidance system coupled with a controller, the guidance system locating the one or more AGVs in an operating environment; an item handling mechanism coupled with the body and the controller, the item handling mechanism adapted to move an item; the controller coupled with the drive unit, the guidance system, and the item handling mechanism, the controller performing operations including: receiving an instruction from a computing system, the instruction identifying a location on a mobile cart in a cart loading zone, the location being assigned to the item; transporting, by the one or more AGVs, the item from an item loading area to a point proximate to the assigned location on the mobile cart, transporting including navigating using the drive unit and the guidance system; placing the item at the assigned location using the item handling mechanism of the one or more AGVs; and transporting, by the one or more AGVs, the mobile cart from the cart loading zone into a delivery vehicle based on the item being placed at the assigned location.

Other implementations of one or more of these aspects include corresponding systems, apparatus, and computer programs, configured to perform the actions of the methods, encoded on computer storage devices.

It should be understood that the language used in the present disclosure has been principally selected for readability and instructional purposes, and not to limit the scope of the subject matter disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure is illustrated by way of example, and not by way of limitation in the figures of the accompanying drawings in which like reference numerals are used to refer to similar elements.

FIG. **1** is an illustration of an example delivery vehicle and automated guided vehicle loading layout.

FIGS. **2**A-**2**D are illustrations of example automated guided vehicles for filling a mobile cart with items.

FIG. **3** is an illustration of an example automated guided vehicle for loading a mobile cart into a delivery vehicle.

FIG. **4** is a flowchart of an example method for automated loading of delivery vehicles using mobile carts and automated guided vehicles.

FIG. **5** is a flowchart of an example method for preparing a mobile cart for receiving items using automated guided vehicles.

FIGS. **6**A and **6**B are flowcharts of an example method for coordinating automated guided vehicles to automatically load delivery vehicles.

FIG. **7** is a flowchart of an example method for sorting items by an automated guided vehicle.

FIG. **8** is a block diagram of an example loading coordination system and data communication flow for automated loading of delivery vehicles using automated guided vehicles.

FIG. **9** is a block diagram of an example computing system.

DESCRIPTION

Among other benefits, the technology described herein improves upon the technology described in the Background Section. For instance, the technology provides robotic devices, systems, methods, and other aspects that can more efficiently prepare mobile carts **116** and delivery vehicles **104**. The technology may automate storage or retrieval of items in a delivery vehicle **104** using robotic technology to support delivery operations. For instance, the technology described herein describes example automated guided vehicles ("AGVs") **102** that efficiently carry items. An item may be a physical object, such as a product, box or container of products, etc. Some implementations of the technology described herein may include a system and method that includes determining locations on a mobile cart **116** and/or in delivery vehicle **104** and manipulating the items to place them in the determined locations on a mobile cart **116** by a first AGV **102** and then moving the mobile cart **116** into the delivery vehicle **104** by a second AGV **102**.

Further, some implementations may include advancements to computing systems, computer logic, conveyor mechanisms **108**, AGVs **102**, delivery vehicles **104**, scanners, guidance systems, mobile carts **116**, and shelving systems for supporting the preparation of delivery vehicles **104** using the AGVs **102**, as described in further detail elsewhere herein. Further, according to some implementations, hardware and computer logic aspects of the technology work together to execute tasks described herein and solve the problems discussed in the Background, for example.

The technologies described herein are beneficial over the previous solutions described in the Background at least because the algorithms and devices may automatically determine storage locations within a delivery vehicle **104** such that items may be efficiently loaded into the delivery vehicle **104**. For instance, the operations and devices described herein may reduce the shuffling of items, distance moved by an AGV **102**, time expended for retrieving the items during delivery, time expended loading items into the delivery vehicle **104**, and/or space used by the items. For example, the systems and logic described herein may identify a list of locations for delivery, sort the items being delivered to the locations, and generate a task for a cart filling AGV **102***a* to place the items on a mobile cart **116** in an efficient manner. The systems and logic may generate a task for a cart loading AGV **102***b* to move the mobile cart **116** into the delivery vehicle **104**, thereby accurately and automatically tracking items loaded into a delivery vehicle **104**, optimizing space utilization, optimizing delivery efficiency, and decreasing physical and mental fatigue of human workers.

The technologies described herein may optimize the amount of space available in a delivery vehicle **104** by externally preparing a mobile cart **116** using a cart filling AGV(s) **102***a* and then, moving the mobile cart **116** into the delivery vehicle **104** using a cart loading AGV **102***b*, for example, because a cart may be too heavy for a human to move. The system may provide improvements in software intelligence to coordinate movements between different AGVs **102**, for example. The technologies beneficially improve productivity, increase asset utilization, decrease physical and mental fatigue, and lower cycle time and labor costs. These benefits, in turn, lead to shorter delivery times and result in significant savings and value.

With reference to the figures, reference numbers may be used to refer to components found in any of the figures, regardless whether those reference numbers are shown in the figure being described. Further, where a reference number includes a letter referring to one of multiple similar components (e.g., component 000a, 000b, and 000n), the reference number may be used without the letter to refer to one or all of the similar components.

FIG. **1** is an illustration of an example delivery vehicle **104** and automated guided vehicle loading environment **100**. As illustrated, the example environment may include a loading bay **106** with a door dock **110** at which a delivery vehicle **104** may be parked, one or more AGVs **102***a* and **102***b* preparing a mobile cart **116** and the delivery vehicles **104** with items to be delivered (or, in some implementations, receiving items being delivered by the delivery vehicles **104**), and, in some implementations, one or more conveyor mechanisms **108** configured to bring items to the loading bay **106**. As discussed in further detail elsewhere herein, some or all of the components of the environment **100** may include communication devices and computer logic allowing coordination of the components in order to more effectively autonomously load the delivery vehicles **104**, for example, as discussed in reference to FIG. **8** and the methods herein. It should be noted that the example environment **100** illustrated in FIG. **1** may be modified with additional or fewer components or a different layout without departing from the scope of this disclosure.

In some implementations, the loading environment **100** may include a cart loading zone **132** (e.g., in the loading bay **106**) in which a mobile cart **116** may be loaded with items, for instance, mobile cart **116***b* is illustrated in an example cart loading zone **132**. In some implementations, the cart loading zone **132** may be an area associated with a door dock **110** and to which a cart filling AGV **102***a* may transport items to place the items on a mobile cart **116** located in the cart loading zone **132**. In some instances, the location of the cart loading zone **132** may be defined within the loading bay **106** relative to the door dock **110**, conveyor **108**, delivery vehicle **104**, etc. For example, the location of a cart loading zone **132** and, in some instances, location of a mobile cart **116** may be defined in X/Y coordinates and/or as an offset from a location, such as a door dock **110**. Accordingly, in some implementations, the loading coordination engine **804** may use the location of the cart loading zone **132** (and/or mobile cart **116**) in combination with the assigned location of an item on the mobile cart **116** when determining a location at which to place an item on a mobile cart **116**. For instance, the loading coordination engine **804** may use the location of the mobile cart **116** and/or cart loading zone **132** to navigate to a point adjacent to the assigned location for an item, as described in further detail in reference to FIG. **4**.

In some implementations, a cart loading zone **132** may include space for a single mobile cart **116** or for multiple mobile carts **116**. The location of the cart loading zone **132** may change depending on which mobile cart **116** is being loaded (e.g., a delivery vehicle **104** may be capable of carrying multiple mobile carts **116**). Further, in some implementations, a cart loading zone **132** may be capable of serving or being associated with multiple door docks **110**, conveyors **108**, conveyor locations, etc., for example, by using time sharing among door docks **110** or by including space for multiple mobile carts **116**. Similarly, a single door dock **110** may have multiple cart loading zones **132** associated therewith, for instance, so that multiple mobile carts **116** associated with a particular delivery vehicle **104** can be loaded simultaneously.

A delivery vehicle **104** may include a truck (e.g., a box truck), trailer (e.g., connected with a truck), van, autonomous vehicle, etc. The delivery vehicle **104** includes a storage area **124** in which mobile carts **116** loaded with items may be placed (e.g., using a cart loading AGV **102***b*, as discussed herein) for transportation to delivery destinations. As illustrated in FIG. **1**, an item may include a carton **114**, although it should be understood that an item may be any physical object.

The storage area **124** may include one or more doors, such as a side door, back door, front door (e.g., in a cab of the delivery vehicle **104**) or even top door, which, in some instances, may be tied to defined operations. For example, a side door may be used for loading or deliveries at locations without loading/unloading docks (e.g., at a curbside), a back door may be used for loading or deliveries at locations with loading/unloading docks, a front door may load items directly into or adjacent to a cab of the delivery vehicle **104**, and a top door may be used with an aerial drone to deliver items from the delivery vehicle **104**. The delivery doors may be associated with delivery destinations and used by the loading coordination engine **804** to determine placement locations of the items on mobile carts **116** to be stored inside of the storage area **124** of the delivery vehicle **104**. For instance, a cart filling AGV **102***a* may automatically place items on a mobile cart **116** based on the specific door that is used during delivery, as described in further detail in reference to FIG. **7**.

The storage area **124** of the delivery vehicle **104** may include a cart lock mechanism adapted to impede certain movement of the mobile cart **116** within the delivery vehicle **104**, for example, the cart lock mechanism may include rails, hooks, magnets, pins, etc. In some implementations, the cart lock mechanism may be mechanically or electronically lockable and/or releasable by an AGV **102** (e.g., a cart loading AGV **102***b*) or other computing device communicatively coupled with the loading coordination engine **804**.

The storage area **124** of the delivery vehicle **104** may include one or more designated locations for one or more mobile carts **116**, which may be adapted to hold multiple items. In some implementations, the mobile carts **116** may be arranged along one side of the storage area **124**, for example, the mobile cart **116** may be on the left side of the storage area **124** to enable movement of an AGV **102** or delivery person along the right side. In some implementations, mobile carts **116** may be arranged along both the left and right side of the storage area **124**.

A mobile cart **116** may include a storage device on which items may be placed, moved, and removed. The mobile cart **116** is configured to be transported between the cart loading zone **132** and the delivery vehicle **104**, for example, by a cart loading AGV **102***b*. The mobile cart **116** may have wheels, a coupling point or mechanism (e.g., via which the cart loading AGV **102***b* may couple with the mobile cart **116**), one or more shelves, one or more bins, and/or a cart lock or component thereof (e.g., via which the mobile cart **116** may be secured to the delivery vehicle **104**).

For example, as illustrated in FIG. **1**, an example mobile cart **116***a* is filled with items and loaded into the storage area **124** of the delivery vehicle **104**. FIG. **1** also illustrates another example mobile cart **116***b* in the cart loading zone **132** being filled by a cart filling AGV **102***a*. In some implementations, once the cart filling AGV **102***a* has added the assigned items to the mobile cart **116***b*, the cart loading AGV **102***b* may transport the mobile cart **116***b* from the cart loading zone **132** into the delivery vehicle **104**.

In some implementations, mobile cart **116**, a shelf on a mobile cart **116**, portion of a shelf, etc., may include a marker (not shown) identifying the mobile cart **116** and/or shelf. For instance, a section of a particular shelf may include a label on the front of the shelf. An AGV **102** (e.g., a cart filling AGV **102***a*) may include a scanner coupled with the carrying device **226** (e.g., described below in reference to FIGS. **2**A-**2**D), platform **218**, etc., that can read signatures or markers to identify the shelf and/or determine its location. For example, the scanner may be an optical scanner configured to read visual identifiers (e.g., labels including a QR code, bar code, etc.) to determine with which shelf the carrying device **226** is aligned.

In some implementations, one or more shelves of a mobile cart **116** may be partial. A partial shelf may extend only partially underneath an item or have one or more indents, gaps, or channels, so that a carrying device **226** may more easily fit under the item to lift the item from the partial shelf or place the item on the partial shelf.

In some implementations, the storage area **124** of a delivery vehicle **104** may also include designated storage places for one or more pallets **126**, for example, for larger orders.

In some implementations, the storage area **124** of a delivery vehicle **104** may include components used in an AGV guidance system of an AGV **102** (e.g., a cart loading AGV **102***b*) to locate itself, a mobile cart **116**, a cart lock mechanism, and/or items in the delivery vehicle **104**. For example, the AGV guidance system may include beacons, QR codes or other symbols, etc., for providing location information to the AGV **102**. For example, the symbols or beacons may be placed on the floor, ceiling, walls, or mobile cart(s) **116** in the storage area **124**. In some implementations, as described in further detail below, an AGV **102** may have an optical or radio sensor for reading the symbols or beacons, which may thereby be used to determine the location and identification of the symbols or beacons and thereby the location of AGV **102**.

In some implementations, a delivery vehicle **104** may include a computing system that communicates with a loading coordination server **802** and/or an AGV **102**, for example, as described in reference to FIG. **8**. The delivery vehicle **104** computing system may include an in-dash computing system, tablet computer, smartphone, laptop, vehicle control unit, or other computing device. In some implementations, the delivery vehicle **104** computing system may perform operations of the loading coordination engine **804** described herein. In some instances, the delivery vehicle **104** computing system may communicate information with an AGV **102** associated with the delivery vehicle **104**. For example, the delivery vehicle **104** computing system and AGV **102** may communicate location, speed, acceleration, current or next delivery, which delivery door to use for a particular delivery, and/or other information.

In some implementations, the delivery vehicle **104** computing system may include or communicate with a location system, such as a global positioning system device (GPS), an accelerometer, or another device capable of determining the location of the vehicle. For instance, the delivery vehicle **104** computing system may determine that the delivery vehicle **104** is arriving at a door dock **110** and transmit a notification message to the loading coordination engine **804** and/or an AGV **102** indicating arrival of the delivery vehicle **104** at the door dock **110**. In some implementations, the loading coordination engine **804** may assign a door dock **110**, route, mobile cart(s) **116**, set of orders, or set of items, etc., to the delivery vehicle **104**. For example, the loading coordination engine **804** may transmit a message to the delivery vehicle **104** computing system with instructions to dock at the assigned door dock **110**.

An AGV **102** is an automated guided vehicle or robot that may be configured to autonomously manipulate items and/or mobile carts **116**, for example, for use with a delivery vehicle **104**, as described herein. The AGV **102** may include a drive unit adapted to provide motive force to the AGV **102** and a guidance system adapted to locate the AGV **102**.

In some implementations, various types of AGVs **102** may be used to specialize in the operations described herein. For instance, a first type of AGV **102** may be a cart filling AGV **102***a*, which may be configured to transport items and, in some instances, place the items at designated locations, such as on shelves of a mobile cart **116**. For example, a cart filling AGV **102***a* may include an IHM (item handling mechanism) **216** (e.g., as described in reference to FIGS. **2**A-**2**D).

For example, the IHM **216** of an AGV **102** may retrieve an item from a conveyor mechanism **108**, pallet **126**, or other loading area, transport the item, manipulate the item, and/or place the item at a designated location, such as on a mobile cart **116** in a cart loading zone **132** or delivery preparation area. A loading area may be any location from which an item may be retrieved by the AGV **102***a*, such as at the door of a delivery vehicle **104**, at a conveyor mechanism **108**, on a shelf, or another defined location. Example implementations of AGVs **102***a* are described in further detail in reference to FIGS. **2**A-**2**D.

In some implementations, another type of AGV **102** may be a cart loading AGV **102***b*, which may be configured to transport mobile carts **116** and, in some instances, lock or release a cart lock mechanism to secure or release the mobile cart **116** in the delivery vehicle **104**. In some implementations, the cart loading AGV **102***b* or a component thereof may be configured to slide under a mobile cart **116** to lift it and transport it. In some implementations, the cart loading AGV **102***b* may be configured to couple with a mobile cart **116** from an end or a side and push or pull the mobile cart **116** into the delivery vehicle **104**. Example implementations of AGVs **102***b* are described in further detail in reference to FIG. **3**.

It should be noted that although multiple types of AGVs **102** (e.g., various cart filling AGVs **102***a* and cart loading AGVs **102***b*) are described herein, the components and/or operations of these various AGVs **102** may be combined or differentiated without departing from the scope of this disclosure. For example, a cart filling AGV **102***a* and a cart loading AGV **102***b* may be combined as a single AGV **102** that can perform both cart filling and cart loading operations.

In some implementations, the loading environment **100** may include a conveyor mechanism **108** for bringing items to the loading bay **106**. For example, the conveyor mechanism **108** may include a conveyor belt, roller wheels, skate wheel conveyor, etc., or may include another device, such as an AGV **102** configured to bring items to the loading bay **106** from a warehouse, for example. The conveyor mechanism **108** may be motor driven or may be driven by gravity, etc. The conveyor mechanism **108** may include handling mechanisms to route items to different door docks **110**, etc. In some implementations, the conveyor mechanism **108** may include or be coupled with scanners that scan items to determine their attributes. For example, a scanner may scan a label on the item, and, based on the content of the label, the loading coordination engine **804** may track an item or determine attributes of the item, such as its delivery destination, weight, dimensions, priority, appropriate delivery vehicle **104** door, etc.

The loading coordination engine **804** may use computer logic to coordinate execution of tasks among the components of the loading coordination system **800**. For example, the loading coordination engine **804** may route items among a conveyor mechanism **108**, cart filling AGV(s) **102***a*, a mobile cart **116** (e.g., which may be transported by a cart loading AGV **102***b*), and delivery vehicle **104**. In some instances, the loading coordination engine **804** may also communicate with a computing system of a warehouse, store, or fulfillment center where the loading bay **106** is located in order to prepare items and coordinate the components of the loading coordination system **800** with the operations of the warehouse, store, or fulfillment center. Details of the operations of the loading coordination system **800** are described in further detail in reference to the flowcharts herein, for example.

In some implementations, the loading coordination engine **804** may direct a conveyor mechanism **108** to bring a particular item to the loading bay **106** (or specific part of the loading bay **106**, particular door dock **110**, particular cart loading zone **132**, etc., associated with a delivery vehicle **104** and/or mobile cart **116**), while, in some implementations, a scanner communicatively coupled with the loading coordination engine **804** may scan an item on the conveyor mechanism **108** thereby determining its attributes (e.g., a delivery vehicle **104**, a location in a delivery vehicle **104**, a delivery destination, its size, etc.).

As illustrated, in some implementations, the loading coordination engine **804** may direct a first AGV **102***a* to retrieve the item from the loading area, transport the item within the loading bay **106**, and place the item at a determined location on the mobile cart **116** in the cart loading zone **132**. As illustrated, a second AGV **102***b* may couple with the mobile cart **116***b* in the cart loading zone **132** and transport the mobile cart **116***b* to a designated location in the delivery vehicle **104**.

It should be noted that the operations described in reference to FIG. **1** are provided by way of example and that other implementations are possible and contemplated herein.

FIGS. **2**A-**2**D are illustrations of example AGVs **202** according to some implementations described herein, for instance, the example AGVs **202** in FIGS. **2**A-**2**D may represent cart filling AGVs **102***a*. FIG. **2**A depicts an example AGV **202***a*, which may include an AGV body **210**, a drive unit **212** housed within or coupled to the body **210**, a power source (not shown) housed within or coupled to the body **210**, an IHM **216**, a guidance system (not shown), and one or more controllers (not shown), although other configurations are possible and contemplated herein. Depending on the implementation, some or all of the features and operations of the example AGVs **202***a*, **202***b*, and **202***c* discussed in reference to FIGS. **2**A-**2**D may be interchanged, omitted, duplicated, or replaced. For example, a feature discussed in reference to the example AGV **202***a* in FIG. **2**A may be used with the AGV **202***b* in FIG. **2**B, or a feature discussed in reference to the example AGV **202***b* in FIG. **2**B may be used with the example AGV **202***a* in FIG. **2**A. Similarly, in some implementations, the AGV **302** described in reference to FIG. **3** may include some of the features described in reference to the AGVs **202** described in FIGS. **2**A-**2**D or vice versa. Further, some features may be described in reference to one of the figures herein (e.g., FIGS. **2**A-**2**D or FIG. **3**), but not the other figures in order to simplify the description and reduce repetition, although they may be applicable to some or all of the figures.

The body **210** may include a front, a rear opposing the front, a left side extending from the front to the rear, and a right side opposing the left side and extending from the front to the rear. The body **210** may be configured to house a drive unit **212**, power source, controller, and/or other components of the AGV **202***a*.

The drive unit **212** may be coupled to the body **210** and configured to receive power from the power source to provide motive force to the AGV **202***a* and propel the AGV **202***a* within an operating environment. In some implementations, the drive unit **212** may receive instructions from one or more controllers instructing the drive unit **212** to cause the AGV **202***a* to move forward, backward, sideways, turn, or perform another movement. In some implementations, the drive unit **212** may include electric motors and wheels, although other configurations, such as treads are possible. In some implementations, the drive unit may include wheels configured to roll along rails or a track in the loading bay **106**, thereby improving stability and the ability of the AGV **102** to locate itself.

The drive unit **212** may be wirelessly coupled via a controller to a wireless interface and a wireless communications network to receive control signals from the loading coordination engine **804** and/or other components of the system **800**. In some implementations, the drive unit **212** may be controlled as described in elsewhere herein, which may be executed using a distributed computing system comprising AGVs **202**, servers (e.g., the loading coordination server **802**), controllers, etc., for example, as shown in the system depicted in FIG. **8**.

The power source may be coupled to the components of the AGV **202***a* to provide power to the components, for example, the power source may provide power to the IHM **216**, the drive unit **212**, a controller, or another component of the AGV **202***a*. The power source may include a battery, a wire, contact track (e.g., integrated with the stability mechanism or otherwise in the delivery vehicle **104** or loading bay **106**), induction charger, alternator or gas generator, etc.

The item handling mechanism or IHM **216** may include a carrying device **226** and, in some instances, a robotic device (e.g., an elevator **208**, adjustable platform **218**, robotic arm, etc.) moving the carrying device **226** to, for example, retrieve items from a loading area and transport them to a designated location on a mobile cart **116**. In some implementations, the IHM **216** may also be configured to retrieve items from shelves and place them at a designated location, such as adjacent to a door in the delivery vehicle **104**, etc.

In some implementations, the IHM **216** may include a robotic arm, platform **218**, or other device for extending a carrying device **226** from an AGV **202** to a mobile cart **116** that is separate from the AGV **202**. In some implementations, the IHM **216** may be configured so that a carrying device **226** fits next to a shelf or other part of a mobile cart **116** when the AGV **202** is at a point proximate to an assigned location on the mobile cart **116**, so that a carrying device **226** does not need to be extended to interact with an item or place it on the mobile cart **116**. In some implementations, the IHM **216** may have one, two, three, or more degrees of freedom to move the carrying device **226** along one, two, three, or more axes thereby allowing the IHM **216** to retrieve an item from a loading area and place the item at a target location, such as on a mobile cart **116**. Similarly, in some instances, the IHM **216** may be configured to retrieve an item from a shelf and place it at a second location, such as adjacent to a door or on a platform for retrieval by a delivery person or delivery AGV **102**.

In some implementations, the IHM **216** may include a mast having an elevator **208** coupled with the body **210**. The elevator **208** lifts and lowers a platform **218** supporting a carrying device **226**. The elevator **208** moves the IHM **216** along a Z axis to lift and set down the item.

In some implementations, a platform **218** extends or retracts the carrying device **226** horizontally between the AGV **202***a* and a mobile cart **116**, loading area, or delivery vehicle **104** door. In some implementations, the platform **218** may also extend or retract the carrying device **226** into or out of one or more of AGV **102** shelves **214** (e.g., as in the example AGV **202***b* illustrated in FIG. 2B) to place an item on one of the AGV shelves **214**.

In some implementations, the platform **218** and/or carrying device **226** may include a set of rollers or a conveyor belt that, when stationary, hold an item in a stationary position on the AGV **202**. In some implementations, the rollers or conveyor belt may turn, thereby moving an item sideways (e.g., in a Y direction) relative to the direction of motion of the AGV **202** and into a shelves on a mobile cart **116**, for example. In some implementations, the rollers or conveyor belt may turn, thereby moving an item forward or backward (e.g., in an X direction) relative to the direction of motion of the AGV **202** and into a shelves on a mobile cart **116**, for example.

In some implementations, the IHM **216** includes a moveable platform **218** supporting a carrying device **226** and capable of translating the carrying device **226** along a plane in one, two, or more dimensions and/or rotating about a vertical axis. For example, the platform **218** (or other component of the IHM **216**, depending on the implementation) may translate the carrying device **226** along X and/or Y coordinates (e.g., sideways/left and right relative to the front of the AGV **202***a*; forward and backward relative to the front of the AGV **202***a*; etc.).

In some implementations, the platform **218** may comprise two platforms coupled to one another, a first of which moves along a first horizontal axis and a second of which moves along a second horizontal axis perpendicular to the first horizontal axis. For instance, the first platform may be coupled with the elevator **208** and the second platform, so that the first platform may move the second platform along the first horizontal axis. The second platform may be coupled with the first platform and the carrying device **226**, so that the second platform may move the carrying device **226** along the second horizontal axis.

In some implementations, the platform **218** may be configured to rotate a carrying device **226**, such as the forks or rollers, so that the carrying device **226** may extend or be extended about a horizontal plane, as described above. For instance, the carrying device **226** may extend and then retract along a first horizontal axis to retrieve an item, as described above. Once the carrying device **226** has retracted, the platform **218** may rotate the carrying device **226**, so that it may be extended along a second horizontal axis, for example, to place the item on a shelf, whether on the AGV **202**, as described in reference to FIG. 2B, or on a mobile cart **116**.

In some implementations, the IHM **216** may include a carrying device **226** in the form of forks, which may extend outward from the AGV **202** to interface with an item, for example, in a loading area or mobile cart **116**, and may be retractable, so the forks may be placed at any desired height and maneuvered underneath an item and to lift the item from a first location during extraction of the item from the loading area or placement of the item on a mobile cart **116**.

In some implementations, the IHM **216** may include a robotic arm, which moves a carrying device **226**. The robotic arm may pivotable or otherwise articulable to extend the carrying device **226** in order to lift the item from a loading area, transport it from the loading area to a designated location, and place it at the designated location. The elevator **208** may raise or lower the robotic arm to interact with various shelves of a mobile cart **116**.

In some implementations, the AGV **202***a* may include a scanner coupled with the carrying device **226**, platform **218**, or body **210**, etc., that can read signatures or markers to determine locations of scanned objects. For example, the scanner may be an optical scanner configured to read visual identifiers (e.g., labels including a QR code, bar code, etc.) to determine with which shelf (or an AGV shelf **214**) the IHM **216** or the carrying device **226** is aligned. The optical scanner may scan a marker on a shelf or other location on a mobile cart **116**, for example. The shelf marker may indicate a position and/or identification of a shelf, for example.

In some implementations, the elevator **208** may include positional sensors to determine the position of IHM **216** and/or to align the carrying device **226** with a target shelf (whether an external or integrated with the AGV **202**, such as an AGV shelf **214**).

The carrying device **226** may be coupled to or integrated with the IHM **216** and is configured to support and/or move one or more items. In some implementations, the carrying device **226** is connected at a distal end of the IHM **216**. The carrying device **226** may be movable by the IHM **216** vertically, for instance. The carrying device **226** may be extendable by the IHM **216** using the range of motion to retrieve a certain item from a loading area, shelf, other AGV **202**, etc., and place the item at a second location within reaching distance of the IHM **216**.

In some implementations, the carrying device **226** may include or have attached thereto, components such as forks, a surface that may extend under an item, arms that may extend to the sides of an item to pinch or otherwise grasp the item, a crane with a claw device to lift an item, a clamp arm, motorized rollers, a conveyor belt, one or more suction cups, rollers, etc., or a combination of two or more such components. For example, a carrying device **226** may include rollers and a suction cup, the suction cup extending (e.g., on an arm) from the carrying device **226** into a mobile cart **116** to push an item from the carrying device **226** onto a shelf of the mobile cart **116**. The suction cup may be powered by a compressor on the AGV **202**, for example. The carrying device **226** may be made of any material, such as plastic or metal, which is sufficiently strong to support an item.

In some implementations, a controller of the AGV **202** may determine attributes of an item to be picked up by the carrying device **226** and use those attributes to more accurately handle the item. For instance, the controller may read a label and/or communicate with the loading coordination engine **804** to determine dimensions and/or weights of the item thereby allowing the controller to determine, for example, a grip or suction force, or a position of the item on the carrying device **226**.

The AGV **202***a* may include a guidance system that determines a location of the AGV **202***a* within an operating environment. For instance, the guidance system may include one or more sensors that detect and process navigation markers (e.g., QR codes, radio frequency identification or RFID labels, etc.) to locate the AGV **202***a* while the AGV **202***a* traverses the operating environment. The guidance system may be coupled to a controller of the AGV **202***a*, which may, in some instances, include local object detection intelligence and processing to avoid collision with other objects (e.g., AGVs **202**, humans, items, mobile carts **116**, etc.) in the operating environment.

In some implementations, the guidance system of the AGV **202** may include an accelerometer, GPS sensor, cellular radio, etc., to determine its location, acceleration, velocity, etc.

The AGV **202***a* may include one or more controllers coupled with the guidance system, IHM **216**, drive unit **212**, loading coordination engine **804**, etc., to perform operations described herein. For instance, the one or more controllers may receive a signal from the loading coordination engine **804** and, in response, may signal the drive unit **212** to propel the AGV **202***a*. The one or more controllers may communicate with the guidance system to determine a location of the AGV **202***a* within the operating environment and, using the drive unit **212**, navigate through the operating environment. For example, the one or more controllers may receive a signal from the loading coordination engine **804** indicating to retrieve a particular item from a retrieval location, such as a loading area, conveyor mechanism **108**, shelf, etc., in response to which, the one or more controllers may instruct the drive unit **212** to position the IHM **216** adjacent to the retrieval location using the current location determined by the guidance system and then direct the IHM **216** to retrieve the item, for example. Similarly, the one or more controllers may instruct the drive unit **212** to position the IHM **216** adjacent to an assigned location of an item, for instance, on a mobile cart **116** in a cart loading zone **132**.

FIG. **2**B describes another example AGV **202***b* with AGV **102** item storage rack **206** with one or more AGV shelves **214**. The example AGV **202***b* may be used both inside and outside of the delivery vehicle **104**, or used solely outside the delivery vehicle **104**, for example. As illustrated, the AGV **202***b* may include an AGV **102** item storage rack **206** with a plurality of shelves arranged vertically. The IHM **216** may also include a mast having an elevator **208** and a platform **218**, which may be raised or lowered using the elevator **208**. The platform **218** may extend the carrying device **226** along a first direction toward the AGV **102** rack **206** or, perpendicularly to the first direction, toward a mobile cart **116** adjacent to the AGV **202**, depending on the implementation.

Some implementations of the AGV **202** may include an AGV **102** item storage rack **206** (also referred to as AGV rack **206**), such as illustrated coupled with the example AGV **202***b*. While the AGV rack **206** is illustrated as coupled to the top of the body **210**, other configurations are possible, for example, the AGV rack **206** may be coupled in front of, behind, to the side of, or even towed or pushed by the AGV **202**. The AGV rack **206** may be positioned proximate to the IHM **216**, so that the shelves **214** are within reach of the IHM **216** for the IHM **216** to place items on or retrieve items from the shelves **214**.

The AGV rack **206** may include a single shelf **214** or a plurality of shelves **214** coupled to a frame. The shelves **214** may include flat surfaces, bays, containers, or other mechanisms for holding an item. Where equipped, a shelf **214** may be capable of storing the item during transit of the AGV **202**.

The plurality of shelves **214** may be vertically arranged and, in some implementations, one or more of the shelves **214** may have an adjustable height (e.g., adjusted manually or automatically using a motor coupled with the AGV **202***b*) on the AGV rack **206**. In some implementations, a controller of the AGV **202***b* may determine a current height of a particular shelf of the plurality of shelves **214** (or, for instance, a loading area, item, other shelves, or a location on the mobile cart **116**), for example, using an optical scanner or retrieving a stored height of a particular shelf from a database. For example, one or more of the shelves **214** may include a marker readable by an optical scanner coupled with the IHM **216** or carrying device **226** to indicate to the IHM **216** a location or identification of the a particular shelf. In some implementations, a controller of the AGV **202***b* may store a shelf identifier for a shelf **214** in association with a height or size of the shelf **214**, or an identifier of an item stored on the shelf **214**.

In some implementations, a shelf **214** onto which an item is placed may be selected based on the size, height, weight capacity, or other attributes of the shelf **214**. For example, an item of a given size may be placed on a shelf **214** having a corresponding size. In another example, in response to an item having a threshold weight, it may be placed on a lower shelf **214** than an item having a lighter weight than the threshold.

It should be noted that, although scanning, adjusting, selecting, etc., are described in reference to the AGV shelves **214** in the AGV rack **206**, the same processes and mechanisms may be used with the shelves described in reference to the mobile cart **116**, for example.

FIGS. **2**C and **2**D describe another example AGV **202***c* with an AGV body **210**, drive unit **212**, elevator **208**, and IHM **216**. The IHM **216** of the example AGV **202***c* may include a carrying device, platform **218**, and carrying surface **232**. The example AGV **202***c* may be used outside of the delivery vehicle **104** to bring items to the delivery vehicle **104** or transport items from the delivery vehicle **104**, may be used both inside and outside of the delivery vehicle **104**, or used solely inside the delivery vehicle **104**, for example. In some implementations, as illustrated in FIG. **2**D, the AGV **202***c* may include a connection point **242** on the body **210** for one or more of a compressor, power, or electronic signal, as described above (e.g., the connection point **242** may be electronically coupled with a controller, IHM **216**, drive unit **212**, or other component of the AGV **202***c*). For example, the connection point **242** may include a data port for programming or control of the AGV **202***c*. In some implementations, the AGV **202***c* may include an auto charger plug point **246** at which the AGV **202***c* may automatically couple with a charger. In some implementations, the AGV **202***c* may include an optical sensor **244** on the body **210**, IHM **216**, etc., which allows the AGV **202***c* to locate itself and/or an item, for example, using a surface of the delivery vehicle **104**, a marker in an operating environment, and/or a label on an item.

FIG. **3** is an illustration of an example AGV **302** for loading a mobile cart **116** into a delivery vehicle **104**. The example AGV **302** may represent an example implementation of a cart loading AGV **102***b*, for example, as described throughout this disclosure. The AGV **302** may include a body **310**, drive unit (not visible in FIG. **3**) housed within or coupled to the body **310**, a power source (not shown) housed within or coupled to the body **310**, a guidance system (not shown), and one or more controllers (not shown), although other configurations are possible and contemplated herein. The drive unit, power source, guidance system, and controllers of the AGV **302** may correspond to those described in reference to FIGS. **2**A-**2**D.

The body **310** may include a front, a rear opposing the front, a left side extending from the front to the rear, and a right side opposing the left side and extending from the front to the rear. While various shapes and construction materials to the body **310** are possible, the body **310** may be configured to fit between rows of shelving in a delivery vehicle **104**, between shelving and a wall of the delivery vehicle **104**, underneath a mobile cart **116**, etc. The body **310** may be configured to house a drive unit, power source, controller, and/or other components of the AGV **302**.

In some implementations, the body of the AGV **302** may be configured to fit underneath a mobile cart **116** while being large enough to accommodate wheels (e.g., as part of the drive unit of the AGV **302**) to allow the AGV **302** to travel over a threshold of the door dock **110**, such as a dock plate. In some implementations, the body may also house a suspension system (not shown) coupled with the drive unit that allows the AGV **302** to travel over uneven surfaces.

The drive unit of the AGV **302** may include or couple with the suspension system to support the body **310**. For example, the suspension system may include a hydraulic or pneumatic suspension that may allow the body **310** to raise or lower. For instance, the body **310** may raise when traversing rough terrain. In another example, the suspension may lower the body to fit under a mobile cart **116** and then lift the body, which in turn may lift the mobile cart **116** and/or couple with the mobile cart **116**, depending on the implementation.

In some implementations, the drive unit may include, for example, wheels mounted to one or more turn tables, casters, treads, etc., to allow the AGV **302** to move in any direction or to rotate, thereby allowing the AGV **302** to navigate within a delivery vehicle **104**.

In some implementations, the AGV **302** may include one or more coupling points **352***a*, **352***b*, **352***c*, and **352***d*, which may couple with corresponding points on a mobile cart **116**. For instance, the coupling points **352** may lift, and/or be lifted by the body **310** and suspension, to couple the AGV **302** with the mobile cart **116**. For example, the coupling points **352** may include recesses that may receive and retain matching protrusions in the bottom of a mobile cart **116**, although other implementations are possible and contemplated herein.

Additionally or alternatively to the coupling points **352**, in some implementations, the AGV **302** may include a coupling mechanism that couples with a mobile cart **116** to push or pull the mobile cart **116**. In some implementations, the coupling mechanism may clamp, grasp, or otherwise attach to the mobile cart **116** to allow the AGV **302** to securely move the mobile cart **116**.

In some implementations, the AGV **302** may include an optical (e.g., laser, infrared, etc.) scanner **354**, which detects markers or objects proximate to the AGV **302**. For instance, the optical scanner **354** may scan a label or navigation marker. In some implementations, the optical scanner **354** may include a LiDAR (light detection and ranging) sensor.

In some implementations, the AGV **302** may include a cart lock interface (not shown), which may be coupled with the body **310**. The cart lock interface may interact with a cart lock on a mobile cart **116** and/or delivery vehicle **104** to lock or release the cart lock. For instance, the cart lock interface on the AGV **302** may exert force on or otherwise signal a cart lock on the mobile cart **116** or delivery vehicle **104** to actuate its locking mechanism. In some implementations, the cart lock interface may include a gear coupled with the AGV **302** that turns a gear causing a cart lock to lock or release.

In some implementations, the cart lock interface may signal or power a motor coupled with a cart lock. For instance, the cart lock interface may wirelessly transmit a signal to a computing device coupled with the cart lock (e.g., in the mobile cart **116** or the delivery vehicle **104**), which in turn causes the computing device to actuate the cart lock. In some implementations, the cart lock interface may include one or more electrical contacts that, when contacting corresponding contacts on the mobile cart **116** or delivery vehicle **104**, sends a signal or provides power to a motor of the cart lock, thereby causing the cart lock to secure or release the mobile cart **116**.

The cart lock, as described elsewhere herein, may include corresponding wireless radios, electrical contacts, or mechanical interfaces (e.g., a gear, clutch plate, etc.) to interact with the cart lock interface of the AGV **302**. In some implementations, the cart lock interface may electrically or mechanically couple with the cart lock allowing the AGV **302** to control the locking and release of the mobile cart **116**, so that when the delivery vehicle **104** moves, the mobile cart **116** does not tip, slide, roll, etc., within the delivery vehicle **104**, but may be removed and transported to a cart loading zone **132** where it may have items placed thereon.

FIG. **4** is a flowchart of an example method **400** for automated loading of delivery vehicles **104** using an AGV **102**. As discussed in reference to FIG. **8**, a loading coordination system may include computing systems associated with a cloud server, AGV(s) **102**, delivery vehicle **104**, conveyor mechanism **108**, or warehouse, etc. In some implementations, a set of items may be inducted into the loading-coordination system in response to receiving item data identifying attributes of the set of items. An order received by the loading coordination engine **804** may include one or more items, a delivery address, delivery or profile attributes, or other information. The loading coordination engine **804** may assign items and/or orders to a delivery vehicle **104** or door dock **110** associated with the delivery vehicle **104** based on delivery destinations of the items, current or projected load of delivery vehicles **104**, etc. The loading coordination engine **804** may instruct a conveyor mechanism **108** to transport the item to the delivery vehicle **104**, door dock **110**, or loading area, and may instruct an AGV **102** to retrieve the item from the loading area and place it at a designated location on the mobile cart **116**. These and other implementations are described in further detail below, for example, in reference to the methods described in FIGS. **4-7**.

In some implementations, the loading coordination engine **804** may transmit a signal(s) identifying items, item attributes, loading areas, delivery vehicles **104**, designated locations in delivery vehicles **104**, etc., to one or more conveyor mechanisms **108**, delivery vehicles **104**, or AGVs **102**. Other information such as identification of a loading area, location on a mobile cart **116**, location in a delivery vehicle **104**, time window for the items to be at designated locations, routing directions, priority, traffic of other AGVs **102**, item dimensions, etc., may also be transmitted in the signal to the components of the loading coordination system **800**.

At **402**, the loading coordination engine **804** may determine a delivery destination of a first item based on item data associated with the first item. In some implementations, the loading coordination engine **804** may receive order information identifying the item and the delivery destination, for example, as received from an e-commerce system, a warehouse system identifying outgoing items/orders, etc.

In some implementations, a scanner or other device communicatively coupled with the loading coordination engine **804** may scan or otherwise capture the item, or label attached to the item, as the item is picked up by an AGV **102**, as the item passes a point on a conveyor mechanism **108** bringing the item from a warehouse or store to the loading bay **106**, or when scanned by a computing device of a human worker. For example, a scanner coupled with the conveyor mechanism **108** and communicatively coupled with the loading coordination engine **804** may scan a label attached to an item as it passes on the conveyor mechanism **108**, and the loading coordination engine **804** may determine a delivery destination and/or assign the item to a door dock **110** (e.g., associated with a particular delivery vehicle **104** and/or delivery route), delivery vehicle **104**, and/or designated location in the delivery vehicle **104** (e.g., as described in reference to FIG. **7**). For instance, a conveyor mechanism **108** may bring the item to the appropriate door dock **110** in the loading bay **106** based on the scanned label.

In some implementations, the loading coordination engine **804** may assign the item to a door dock **110** associated with a delivery vehicle **104**, a delivery vehicle **104** associated with a particular door dock **110**, a mobile cart **116** associated with a delivery vehicle **104**, etc., based on the delivery destination of the item, as described in further detail below.

At **404**, the loading coordination engine **804** may assign the first item to a location on a mobile cart **116**, for instance, based on defined criteria determined for the first item. The assignment to the location may be based upon the delivery destination of the item, the door of the delivery vehicle **104** to be used (e.g., as identified in the order or item data; that will be near the assigned location on the mobile cart **116**, etc.), dimensions of the item, weight of the item, dimensions of available spaces on the mobile cart **116**, or other factors, as described elsewhere herein.

In some implementations, the loading coordination engine **804** may determine a correlation of available or assigned locations on a mobile cart **116** with where those locations will be once the mobile cart **116** is placed in a designated location in the delivery vehicle **104**. For instance, a location may assigned in a storage area **124** of a given delivery vehicle **104** and transformed into a mobile cart **116** location or vice versa, based on a location of a mobile cart **116** relative to the storage area in which the mobile cart **116** is located (e.g., current, previous, designated, assigned, etc., location) a delivery vehicle **104**.

In some implementations, items are assigned to locations on the mobile cart **116** and/or in the delivery vehicle **104** based on the order in which they are received by the AGV **102** (e.g., a cart filling AGV **102***a*). For example, the AGV **102** may place items received at a first end of the mobile cart **116** and moving toward a second end (or from top to bottom, front to back, etc.). An example method for assigning items to locations on the mobile cart **116** and/or in the delivery vehicle **104** is described in reference to FIG. **7**.

In some implementations, at **406**, the loading coordination engine **804** may determine whether there is an additional item assigned to the mobile cart **116** and/or delivery vehicle **104**. In response to determining that there is an additional item, the loading coordination engine **804** may determine the delivery destination of the next item and assign the next item to a location on the mobile cart **116** by iterating the operations at **402** and **404**. In response to determining that there is not (or not yet, as described below) an additional item in a queue of items to be assigned or that have been assigned to the mobile cart **116** and/or delivery vehicle **104**, the method **400** may continue to **406**, for example. It should be noted that the operation **406** may occur in another order in the method **400** or be omitted, depending on the implementation.

At **408**, the loading coordination engine **804** may generate a task list including instruction(s) to an AGV(s) **102** to perform operations to prepare items for a delivery vehicle **104**. The task list may include tasks for the placing a current item and/or a series of items on the mobile cart **116**, transporting items to a mobile cart **116**, transporting mobile carts **116** into delivery vehicles **104**, etc. For example, the loading coordination engine **804** may generate a task list including a first instruction to a first AGV **102***a* to position the item on the mobile cart **116** based on the assigned location and a second instruction to a second AGV **102***b* to transport the mobile cart **116** to a delivery vehicle **104**.

In some implementations, the task list may include one or more tasks identifying one or more items to retrieve, transport, and/or place at a designated location on a mobile cart **116**. The task list may also include one or more tasks identifying a mobile cart **116**, a delivery vehicle **104**, and/or a location in a delivery vehicle **104**. In some implementations, the task list may be specific to each component of the loading coordination system (e.g., a cart filling AGV **102***a*, a cart loading AGV **102***b*, a delivery vehicle **104**, or a conveyor mechanism **108**) or may include tasks for multiple components (e.g., AGV **102***a* and **102***b*). Example tasks that may be included in the task list may be described in further detail below, for instance, in reference to FIGS. **4-7**.

In some implementations, the task list may include a defined route of a cart filling AGV **102***a* in the loading bay **106** and/or the delivery vehicle **104**. The task list may additionally or alternatively identify movements of an IHM **216** of the cart filling AGV **102***a*, for example, as described in reference to FIG. **6**A. The task list may, in some instances, include a schedule indicating when to retrieve items, place items at designated locations, lock into place using a stability mechanism in the delivery vehicle **104**, or perform other operations.

In some implementations, the task list may include a defined route of a cart loading AGV **102***b* in the loading bay **106** and/or the delivery vehicle **104**. The task list may identify movements of the cart loading AGV **102***b* relative to the mobile cart **116** or delivery vehicle **104**, operations of a cart lock mechanism in the delivery vehicle **104**, or a coupling mechanism **352** of the cart loading AGV **102***b* allowing the cart loading AGV **102***b* to couple with the mobile cart **116** during transportation of the mobile cart **116**, among other potential operations. The task list may include a schedule and/or conditions defining when to move the mobile cart **116**, lock the mobile cart **116** in place, etc., as described herein.

At **410**, the loading coordination engine **804** may transport the item(s) to the assigned locations on the mobile cart **116** using an AGV **102** (e.g., a cart filling AGV **102***a*). The cart filling AGV **102***a* may transport one or more items from an item loading area to a point proximate to the assigned location on the mobile cart **116**. For instance, the loading coordination engine **804** may transmit an instruction including or based on the task list to a controller of the AGV **102** to navigate the AGV to an item loading area, retrieve the item from the item loading area, and then navigate to a point proximate to the assigned location on the mobile cart **116**, which may be located in a cart loading zone **132**. Further detail of **410** may be found in the example operations of the AGV(s) **102** for navigation and transportation of items described in further detail in reference to FIG. **6**A.

At **412**, the loading coordination engine **804** may instruct a controller of the AGV **102** to place place, by the AGV **102** (e.g., a cart filling AGV **102***a*), the first item at the assigned location on the mobile cart **116** based on the task list. For example, the AGV **102** may automatically put an item on a shelf of the mobile cart **116**. In some implementations, the AGV **102** may place the item at an assigned location and/or in a defined sequence, for example, as determined in the example method described in reference to FIG. **7**. In some implementations, the AGV **102** may articulate an IHM **216** to put the item on the shelf, for example, as described in the example method of FIG. **6**A.

In some implementations, at **414**, the loading coordination engine **804** may determine whether there is an additional item to be placed on the mobile cart **116** (e.g., based on the task list). In some implementations, in response to determining that there is an additional item, the method **400** may continue to operation **402** where the loading coordination engine **804** determines a delivery destination of the next item and/or assigns the next item to a location on the mobile cart **116** (e.g., by iterating the operations at **402** and/or **404**). In some implementations, in response to determining that there is an additional item, the loading coordination engine **804** may continue to operation **410** (e.g., when a destination has been determined and/or a location has been assigned for the next item) where the next item is transported to the assigned location on the mobile cart **116** by the cart filling AGV **102***a* (e.g., by iterating the operations at **410** and/or **412**). In response to determining that there is not (or not yet, as described below) an additional item to be loaded on to the mobile cart(s) **116** (e.g., based on the task list or a presence of the next item at the loading area), the method **400** may continue to **416**.

In some implementations, at **416**, the loading coordination engine **804** may instruct the AGV **102** to transport the mobile cart **116** from the cart loading zone **132** into a securable position in the delivery vehicle **104** using. For instance, the loading coordination engine **804** may transmit an instruction including or based on the task list (e.g., based on the task list or completion thereof) to a cart loading AGV **102***b* to transport the mobile cart **116** to a defined location in the delivery vehicle **104**. For example, the cart loading AGV **102***b* may navigate to a mobile cart **116** in a cart loading zone **132**, couple with the mobile cart **116**, and then navigate to the delivery vehicle **104** to place the mobile cart **116** in or on the delivery vehicle **104**. Further detail of the operation at **416** may be found in the example operations described in further detail in reference to FIG. **6**B. A securable position may be a position or location at which the mobile cart **116** may be secured to the delivery vehicle **104**, for example, using a cart lock as described below.

In some implementations, at **418**, the loading coordination engine **804** may secure the mobile cart **116** to the delivery vehicle **104**, for example, in response to the mobile cart **116** arriving at a designated location in the delivery vehicle **104**. In some implementations, for instance, the loading coordination engine **804** may signal a cart loading AGV **102***b*, delivery vehicle **104**, component of the mobile cart **116**, or computing device associated with a human. For instance, the signal may include instructions that the mobile cart **116** be secured in place, for example, using a cart lock mechanism, which may lock the wheels and/or couple the mobile cart **116** to the storage area **124** of the delivery vehicle **104**.

In some implementations, once the mobile cart **116** is secured to the delivery vehicle **104**, the loading coordination engine **804** may instruct one or more AGVs **102** to prepare and/or transport a subsequent mobile cart **116** to the same or a different delivery vehicle **104**.

It should be noted that the method **400** described in reference to FIG. **4** is provided by way of reference and that the method **400** may be performed with additional or fewer steps or features.

FIG. **5** is a flowchart of an example method **500** for preparing a mobile cart **116** for receiving items using automated guided vehicles. For instance, the method **500** may prepare a delivery vehicle **104** and/or mobile cart **116** in a delivery vehicle **104** to receive items in orders.

In some implementations, at **502**, the loading coordination engine **804** may create a new delivery task. For example, one or more orders including items may be inducted into the loading coordination system **800**, as described in further detail above. In some implementations, a delivery task may include one or more items, orders, mobile carts **116**, delivery routes, etc., that may be assigned to the delivery vehicle **104** or to which the delivery vehicle **104** may be assigned or otherwise associated.

In some implementations, at **504**, the loading coordination engine **804** may assign a delivery vehicle **104** to a door dock **110** (e.g., at a loading facility) or a door dock **110** to the delivery vehicle **104** based on the delivery task. A door dock **110** may be assigned based on availability of door docks **110**, proximity of a door dock **110** to items (e.g., in a storage area of a fulfillment center) assigned to the delivery vehicle **104**, a previously prepared mobile cart **116** assigned to the delivery vehicle **104**, or other criteria.

In some implementations, at **506**, the loading coordination engine **804** may receive notification message of arrival of the delivery vehicle **104** at the door dock **110**. For instance, a computing system of the delivery vehicle **104** may transmit a GPS coordinate, a notification message, or other signal to the loading coordination engine **804** indicating that the delivery vehicle **104** has arrived or is arriving at the door dock **110**. In some implementations, the signal may be transmitted in response to a door of the delivery vehicle **104** opening.

In some implementation, at **508**, the loading coordination engine **804** may release a cart lock to release the mobile cart **116** from the delivery vehicle **104**. For example, the loading coordination engine **804** may transmit an instruction to release a cart lock, which is configured to secure the mobile cart **116** to the delivery vehicle **104**. In some implementations, the instruction may be received by a computing device coupled with an electronically actuatable cart lock. For instance, a computing device of a delivery vehicle **104** or mobile cart **116** may actuate the cart lock to release it. In some implementations, the instruction may be received by a controller of a cart loading AGV **102***b*, which may navigate the cart loading AGV **102***b* into the delivery vehicle **104** and release the cart lock.

In some implementations, at **510**, the loading coordination engine **804** may couple a cart loading AGV **102***b* with the mobile cart **116**. For instance, the loading coordination engine **804** may instruct a controller of the cart loading AGV **102***b* to navigate the cart loading AGV **102***b* into the storage area **124** of the delivery vehicle **104** via the door dock **110** and couple with the mobile cart **116**.

In some implementations, at **512**, the loading coordination engine **804** may transport the mobile cart **116** from the delivery vehicle **104** to a cart loading zone **132** (assigned) using the cart loading AGV **102***b*. For instance, the loading coordination engine **804** may transmit an instruction to the controller of the cart loading AGV **102***b* to navigate the cart loading AGV **102***b* along a given route and/or to a defined location. For instance, the cart loading AGV **102***b* may navigate, transporting the mobile cart **116**, out from the delivery vehicle **104** to a cart loading zone **132**, which the loading coordination engine **804** may locate based on the door dock **110** assignment.

FIGS. **6**A and **6**B are flowcharts of an example method **600** for coordinating automated guided vehicles to automatically load delivery vehicles **104**. The operations of the example method **600** are provided by way of example and other operations and mechanisms are possible and contemplated herein. In some instances, a loading coordination engine **804** or software on a controller of the cart filling AGV **102***a* may direct the cart filling AGV **102***a* to perform some or all of the operations described in reference to FIG. **6**A. Similarly, a loading coordination engine **804** or software on a controller of the cart loading AGV **102***b* may direct the cart loading AGV **102***b* to perform some or all of the operations described in reference to FIG. **6**B.

In some implementations, at **602**, the loading coordination engine **804** may instruct a component of the loading coordination system **800** to deliver the first item to a loading area (e.g., at a door dock **110**, cart loading zone **132**, etc., associated with the delivery vehicle **104**). For instance, the loading coordination engine **804** may issue an instruction to a conveyor mechanism **108**, AGV **102**, or a warehouse sorting mechanism. For example, an outbound warehouse system (which may include a human worker, AGV **102**, conveyor mechanism(s) **108**, etc.) may place an item on a conveyor mechanism **108** or an AGV **102** that may bring the item to the loading area associated with the delivery vehicle **104** and/or mobile cart **116**. In some implementations, a conveyor mechanism **108** may include sorting mechanisms associated with door docks **110**, which may be used to transport items to the specific door docks **110**.

In some implementations, the loading coordination engine **804** may transmit instructions to a conveyor mechanism **108**, an AGV **102**, or a computing device of a human worker, which instructions may indicate to transport a particular item to a given location (e.g., a particular door dock **110**, loading area, AGV **102**, etc.) at a defined time or in response to a defined trigger (e.g., an item arriving at a defined location on the conveyor mechanism **108**, the AGV **102** arriving at the loading area, etc.).

At **604**, the loading coordination engine **804** may navigate (and/or issue instruction(s) to navigate) the AGV **102** (e.g., a cart filling AGV **102***a*) to a loading area to retrieve the first item from the loading area, which may be located on or adjacent to a conveyor mechanism **108**, in the loading bay **106**, or otherwise in a fulfillment center at which the cart loading zone **132** is located. In some implementations, the AGV **102** may follow a track, series of guidance system markers (e.g., QR codes, RFID tags, etc.), laser navigation points, etc., to navigate between its current location and the loading area. For example, a guidance system of the AGV **102** may read guidance system/navigation markers and follow them until a destination defined by the loading coordination engine **804** is reached. In some instances, the AGV **102** may stop adjacent to the location in order for the IHM **216** of the carrying device **226** to lift the item from the loading area.

In some implementations, at **606**, the AGV **102** (e.g., the cart filling AGV **102***a*) may retrieve the item from the item loading area. For instance, the loading coordination engine **804** may instruct a controller of the AGV **102** to retrieve the item. In some implementations, the AGV **102** may articulate the IHM **216** to grasp, slide under, lift, or otherwise move the item onto the carrying device **226** and/or a shelf **214** of the AGV **102**.

In some implementations, an AGV **102** may be fed by a conveyor mechanism **108**, human worker, or another AGV **102**, etc. For example, the loading coordination engine **804** may instruct an AGV **102** to retrieve an item from a loading area at the end, or another part, of a conveyor mechanism **108** at a given time or in response to a defined trigger (e.g., an item passing a given point on a conveyor belt, reaching the end of a conveyor belt, etc.). In some instances, the loading coordination engine **804** may instruct the AGV **102** to wait at the loading area for a conveyor mechanism **108**, human worker, or another AGV **102** to place the item on a carrying device **226** of the AGV **102**.

In some implementations, where the cart filling AGV **102***a* includes multiple shelves **214** where items may be stored (e.g., as in the AGV **202***b* described in reference to FIG. 2C), the IHM of the AGV **102** may retrieve multiple items from the loading area and place them on one or more AGV shelves **214**.

At **608**, the loading coordination engine **804** may instruct a controller of the AGV **102** to navigate the AGV **102** with the item to a point proximate to the assigned location on the mobile cart **116**, for instance, when the mobile cart **116** is in the cart loading zone **132**. For example, the loading coordination engine **804** (and/or another component of the loading coordination system **800**) may determine the point proximate to the assigned location on the mobile cart **116** based on a location of the mobile cart **116**, a location of the cart loading zone **132**, the assigned location of the item on the mobile cart **116**, and/or a range of motion of an IHM **216** of the cart filling AGV **102***a*. For instance, after retrieving the item from the loading area, the AGV **102** may transport the item to the assigned location. For example, the AGV **102** may navigate to a point/location adjacent to the assigned location of the item such that the IHM **216** of the AGV **102** may place the item at the assigned location. For example, a point proximate to the assigned location may be a position that is within the range of movement of the IHM **216** to place the item at the assigned location or on a shelf where the assigned location is found. The proximate point may be at a defined offset to the assigned location of the item or to a shelf on which the assigned location is found, for example, based on the range of motion of the IHM **216**.

In some implementations, the autonomous navigation may be performed according to routing instructions in the task list. In some instances, the task list may include the assigned location of the item and the AGV **102** may automatically navigate, for example, by following the guidance system markers to the assigned location. In some implementations, the loading coordination engine **804** may define the details of the navigation, such as the guidance system markers, directions, movements, etc., of the AGV **102**, and provide the details to the AGV **102**.

In some implementations, the guidance system may include an optical scanner on a body of the AGV **102** that reads visual markers (e.g., QR codes) on a floor of the operating environment. In some implementations, the guidance system may include laser-based guidance systems, such as LIDAR (light imaging, detection, and ranging). A controller of the AGV **102** may look the visual marker up in an accessible database, such as the map data **822**.

At **610**, the AGV **102** may place the item at the assigned location on the mobile cart **116**. In some implementations, the loading coordination engine **804** (or a component thereof) may instruct a controller of the cart filling AGV **102***a* to perform specific movements to place the item at the assigned location, although controller logic on the AGV **102** may additionally or alternatively automatically perform these operations based on the assigned location received from the loading coordination engine **804**.

In some implementations, placing the item at the assigned location based on the task list includes articulating an IHM **216** of the cart filling AGV **102***a* to a height matching a shelf of the mobile cart **116** at which the assigned location is located, and transferring the item from the IHM **216** to the shelf at the assigned location. For example, a controller of the AGV **102** may instruct the IHM **216**, or a component thereof, to raise or lower the carrying device **226** vertically and, in some instances, move the carrying device **226** sideways, forwards, or rearwards relative to the direction of movement of the AGV **102** to place the item on a shelf of the mobile cart **116**.

In some implementations, the IHM **216** may lift the carrying device **226**, which in turn lifts the item vertically. The carrying device **226** may support the item directly by engaging with the item (e.g., sliding underneath the item, coupling to the sides or front of the item, etc.). For example, the AGV **102** may elevate the carrying device **226** to a height based on the height of the shelf on which the assigned location is located. For instance, the AGV **102** may raise the carrying device **226** toward the storage shelf and stop once a scanner (e.g., coupled with the IHM **216** or carrying device **226**) of the AGV **102** detects a shelf marker (e.g., a barcode, QR code, etc.). For example, the AGV **102** may use a unique identification code of the marker scanned from the marker compared to instructions received from the loading coordination engine **804** to identify a shelf, depending on the implementation.

In some implementations, the AGV **102** may move the carrying device **226** toward the shelf to place an item on top of the shelf at the assigned location. For instance, the IHM **216** (e.g., using the elevator **208**) may raise or lower the carrying device **226** to align it above a shelf and then extend the carrying device **226** toward the shelf to set the item on the shelf. For example, the IHM **216** may raise the carrying device **226** along at least a third axis (e.g., the vertical or Z axis) until the item is above a particular shelf on the mobile cart **116**. The IHM **216** may then lower the carrying device **226** along at least the third axis to place the second item on the shelf. In some instances, the AGV **102** may disengage the carrying device **226** from the item once the item is resting on the shelf.

In some implementations, the carrying device **226** may extend into a shelf on the mobile cart **116** to push the item to appropriate depth to be at the assigned location or, for example, until the item hits the back of a shelf or an item behind it on the shelf.

In some implementations, at **612**, the loading coordination engine **804** may determine whether there is an additional item to be placed on the mobile cart **116** (e.g., based on the task list). If there is an additional item, the method **600** may return to **604** to retrieve another item from the loading area. In some implementations, where the cart filling AGV **102***a* includes multiple shelves **214** where items may be stored (e.g., as in the AGV **202***b* described in reference to FIG. **2**B), the IHM **216** of the cart filling AGV **102***a* may retrieve an item from an AGV **102** shelf **214**. In some implementations, if there are no additional items to be loaded to the mobile cart **116**, the method **600** may continue to **614**, as illustrated in FIG. **6**B.

In some implementations, at **614**, an AGV **102** (e.g., a cart loading AGV **102***b*) may navigate to the mobile cart **116** in the cart loading zone **132**. For instance, the cart loading AGV **102***b* may navigate to the mobile cart **116** based on the task list and/or an instruction from the loading coordination engine **804**. In some implementations, the mobile cart **116** may include a coupling point coupling mechanism corresponding to a coupling point **352** or mechanism on the cart loading AGV **102***b*. For instance, the cart loading AGV **102***b* may navigate to the cart loading zone **132** and align the cart loading AGV's **102***b* coupling point **352** or mechanism with the coupling point on the mobile cart **116**. For example, the cart loading AGV **102***b* may navigate using a guidance system, location of the mobile cart **116** (e.g., stored in the map data **822**, location assignment data **824**, etc.), location of the cart loading zone **132**, and/or computer vision, which may be described above in reference to the AGVs **102**.

At **616**, the AGV **102** may couple with the mobile cart **116**, for example, based on the loading coordination engine **804** instructing a controller of the AGV **102** to couple with the mobile cart **116**. In some implementations, the coupling mechanism of the cart loading AGV **102***b* may attach the cart loading AGV **102***b* to the coupling point of the mobile cart **116**. In some implementations, the cart loading AGV **102***b* may lift the mobile cart **116**, for example, if the mobile cart **116** does not have wheels or if the wheels of the mobile cart **116** are too small to allow it to roll over a dock plate and into a delivery vehicle **104**. For instance, the cart loading AGV **102***b* may travel under the mobile cart **116** and, once under the mobile cart **116**, may lift the mobile cart **116** off the ground.

At **618**, the AGV **102** (e.g., a cart loading AGV **102***b*) may transport the mobile cart **116** into the delivery vehicle **104** by navigating into the delivery vehicle **104** while coupled with the mobile cart **116**, for example, based on an instruction received by a controller of the AGV **102** from the loading coordination engine **804**. In some implementations, navigating the cart loading AGV **102***b* with the mobile cart **116** using a guidance system of the cart loading AGV **102***b* includes applying motive force to the mobile cart **116** by the cart loading AGV **102***b* to transport the mobile cart **116** into the delivery vehicle **104** and following guidance system markers, operating environment coordinates, and/or physical attributes of the operating environment.

In some implementations, the mobile cart **116** may be assigned to a designated location in the delivery vehicle **104**, and the cart loading AGV **102***b* may transport the mobile cart **116** to the designated location. In some instances, the delivery vehicle **104** (and/or mobile cart **116**) may be configured to hold multiple mobile carts **116**. For example, a mobile cart **116** may be configured or filled (e.g., as described in reference to FIGS. **6**A and **7**) such that one side of the mobile cart **116** is placed toward a walkway, toward a wall, etc., of the storage area **124** of the delivery vehicle **104**, depending on the implementation.

In some implementations, at **620**, the loading coordination engine **804** may secure the mobile cart **116** to the delivery vehicle **104**. For example, securing the mobile cart **116** to the delivery vehicle **104** may include actuating a cart lock in response to an AGV **102** transporting the mobile cart **116** to a designated location in the delivery vehicle **104**. In some instances, the loading coordination engine **804** may transmit an instruction to the cart loading AGV **102***b*, delivery vehicle **104** computer, computing device coupled with the cart lock, or another device based on or including a task in the task list instructing the mobile cart **116** to be secured to the delivery vehicle **104**.

For example, the cart loading AGV **102***b* may receive the instruction and, in response, actuate a cart lock that secures the mobile cart **116** to the delivery vehicle **104**. In some implementations, the cart loading AGV **102***b* may apply a torque, pressure, or other mechanical force to via an interface to lock or release the cart lock. In some implementations, the cart loading AGV **102***b* may provide an electrical current instructing or causing the cart lock to lock or release. For example, the cart loading AGV **102***b* may include a cart lock interface to secure the mobile cart **116** that receives power, whether electrical or mechanical, to trigger the cart lock. For instance, the cart lock may include a gear, pin, lever, clamp, etc., which may be actuated by a physical torque or other motive force provided by the cart loading AGV **102***b*, or delivery vehicle **104**, among other potential components.

In some implementations, at **622**, the cart loading AGV **102***b* may decouple from the mobile cart **116** and navigate out of the delivery vehicle **104**. For example, the cart loading AGV **102***b* may use the guidance system(s) and operations described above to navigate from the delivery vehicle **104** to a waiting location, the cart loading zone **132**, a subsequent mobile cart **116**, or other location.

It should be noted that the method **600** of FIGS. **6**A and **6**B may have additional or fewer operations and may be performed with different components. Further, some or all of the operations may be repeated as appropriate and/or needed for any suitable number of items.

FIG. **7** is a flowchart of an example method **700** for sorting items to be loaded by an AGV **102** (e.g., a cart filling AGV **102***a*) onto a mobile cart **116**. The method **700** may describe an inventory sorting algorithm to optimize the outbound process, for example, the AGV **102** may logically shuffle or arrange orders to prepare one or more mobile carts **116** in delivery vehicle **104**, for example, for a sequence of deliveries.

At **702**, the loading coordination engine **804** may determine a set of items assigned to a delivery vehicle **104** and/or mobile cart **116** associated with the delivery vehicle **104**. For example, delivery vehicle **104** may have a given capacity, deliver to a defined geographic area, or otherwise have certain orders and/or items assigned to the delivery vehicle **104**. For instance, a delivery vehicle **104** may have a geographic area assigned to it and the loading coordination engine **804** may assign orders with delivery destinations in that geographic area to the delivery vehicle **104**. In some instances, assignment of the items to delivery vehicles **104** and/or mobile carts **116** may occur as items are delivered to the loading area (e.g., by the conveyor mechanism **108**, as described above)

In some implementations, the loading coordination engine **804** may determine one or more mobile carts **116** in the delivery vehicle **104** or assigned to the delivery vehicle **104** and divide the set of items among the one or more mobile carts **116**. In some implementations, the items may be further divided based on locations (e.g., a front or a back) on the mobile cart **116** to which items may be assigned or based on other criteria, as described below.

In some implementations, at **704**, the loading coordination engine **804** may determine a sequence of deliveries of the set of items assigned to the delivery vehicle **104** (and/or mobile cart **116**, depending on the implementation) based on delivery destinations of the set of items. For example, each item in the set of items may be associated with a delivery destination, which may be a geographic location. The sequence of deliveries may be determined based on a route through the delivery destinations. For instance, a mapping application may determine a route mapped through the delivery destinations of the set of items. In some implementations, the loading coordination engine **804** may determine a position in the sequence of deliveries for a delivery of a particular item assigned to the delivery vehicle **104**.

It should be noted that an order may have one or more items (e.g., multiple boxes, multiple products, etc.) and a given delivery destination may have one or more orders. When a delivery destination has multiple items, the items at that destination may be sequenced based on the order to which they belong, the size or type of the items, arbitrarily, or the items may have occupy the same position in the sequence.

At **706**, the loading coordination engine **804** may determine measurements of items in the set of items assigned to the delivery vehicle **104**. In some implementations, the measurements stored in item data **830** that may be determined based on scanning or otherwise capturing a label of the item, for example. For example, the loading coordination engine **804** may look up item or order data **826** pertaining to the item in a database **820**, where the dimensions and other attributes of the item may be stored. In some implementations, the measurements may be automatically determined using an optical scanner or other measurement method.

If the dimensions of an item exceeds a defined threshold size or weight. For example, if the item is a pallet **126** (e.g., as illustrated in FIG. **1**) of products or a particularly large or heavy item, the item may be automatically assigned to a pallet location in the delivery vehicle **104** or marked as exceeding a threshold dimension. Such an item may be automatically flagged by the loading coordination engine **804** to be manually loaded by a human worker, for example.

At **708**, the loading coordination engine **804** may determine measurements of available storage locations on one or more mobile carts **116** (e.g., a current mobile cart **116** being loaded, a set of mobile carts **116** associated with a delivery vehicle **104**, etc.). For example, there may be a defined quantity and configuration of storage locations on shelves of a mobile cart **116**, pallets, or in other locations in the delivery vehicle **104**. A storage location may have a defined weight capacity, height, width, etc. In some implementations, an available storage location may be a subdivision of a shelf or other portion of a mobile cart **116** and may, for instance, have a variable size based on the quantity and size of items assigned to or already stored on the shelf and/or portion of a mobile cart **116**. For example, an item with a particular depth (or other dimension) that is less than the amount of available space on a shelf on the mobile cart **116** may be assigned to the shelf, thereby decreasing the remaining amount of available space on the shelf to which an additional item may be assigned. For example, once the item is assigned to the available storage location, that storage location may be marked in a database as assigned to the item and the remaining available space on the shelf, portion of the mobile cart **116**, or mobile cart **116** may be recalculated and left in the database **820** for future assignment to another item.

In some implementations, the loading coordination engine **804** may cube the dimensions of the item and the available storage location on the mobile cart **116** to facilitate assignment of the items to the mobile cart **116**. Cubing the dimensions of an item or available space may include determining a cube having dimensions such that the item (e.g., for an irregularly shaped item) may fit in the cube or a cube that would fit in the available space. For instance, cubing may include generalizing an irregularly shaped space to be rectangular (e.g., as in a rectangular prism or cube).

In some implementations, delivery vehicles **104** and/or mobile carts **116** may vary in configuration. As such, in some instances, a loading coordination engine **804** may determine the number, size, location, and/or configuration of available storage locations on the particular mobile cart(s) **116** to which items may be assigned. These and other attributes may be linked with the particular delivery vehicle **104** in delivery vehicle data **832** or cart data **834** in an accessible database (e.g., the database **820** described in reference to FIG. **8**), depending on the implementation.

At **710**, the loading coordination engine **804** may determine and/or assign storage locations on the mobile cart **116** and/or in the delivery vehicle **104** for items in the set of items. For instance, the determination of the storage locations may be based on the measurements of the items, measurements and availability of storage locations in on the mobile cart **116**, a location or orientation of the particular mobile cart **116** in the delivery vehicle **104**, and/or positions of the items in the sequence of deliveries. In some implementations, the location assignments of items may be stored in a database **820**.

In some implementations, the loading coordination engine **804** may use the location of a mobile cart **116** in a delivery vehicle **104** (or the location to which the mobile cart **116** is assigned, for example) to assign items to the mobile cart **116**. For instance, a mobile cart **116** may have a first side and a second side where the first side will be placed against a wall and the second side placed away from the wall in the delivery vehicle **104**. The loading coordination engine **804** may determine a location and/or orientation of the mobile cart **116**, for example, the location and/or orientation of the mobile cart **116** may be assigned to the mobile cart **116**, or determined based on the configuration of the mobile cart **116**. For instance, a particular mobile cart **116** may be designed to have a particular orientation or location in the delivery vehicle **104** and the location and/or orientation may be stored to cart data **834** or determined by a sensor of the cart filling AGV **102***a* or cart loading AGV **102***b*, such as a camera, QR code reader, RFID tag reader, etc.

In some implementations (e.g., where multiple mobile carts **116** are assigned to a delivery vehicle **104**), the sizes, shapes, and/or orientations of each mobile cart **116** may be different and the assigned locations may be determined and/or the mobile carts **116** may be filled and loaded into the delivery vehicle **104** based on the specific configuration of the mobile cart **116**. For example, a mobile cart **116** may have a slope, or other mechanism, for moving items from a back side (e.g., to be placed toward a wall of the delivery vehicle **104**) to a front side (e.g., to be placed toward a walkway or door of the delivery vehicle **104**) of the mobile cart **116** to allow items to more easily loaded or unloaded from the mobile cart **116**.

In some implementations, the loading coordination engine **804** may use a door of the delivery vehicle **104** to be used at delivery to assign the item to a location in the mobile cart **116**. The loading coordination engine **804** may assign items near to the delivery door that will be used during delivery, so that items for a particular door may be near to the door. For instance, a delivery destination may have a delivery door associated therewith, and items may be assigned to a location of a mobile cart **116** near the door with the item/delivery destinations in the delivery vehicle **104**, for example, based on an available location of a mobile cart **116** and the location at which the mobile cart **116** will be placed in the delivery vehicle **104**. For example, at delivery, a rear door may be used with a door dock **110**, a side door may be used for curbside delivery, a top door may be used with a delivery drone, etc.

In some implementations, the loading coordination engine **804** may assign the items to available shelving locations on the mobile cart **116** based on the dimensions of the items and of the available shelving locations. In some instances, items of a given weight may be matched to a shelf having a corresponding weight capacity range (e.g., a heavier duty and/or lower height shelf may hold heavier items). In some instances, some shelves may have a larger available space (e.g., the height above the shelf may be larger) than other shelves and items may be assigned according to their size. For example, an item may be assigned to the smallest shelf that has sufficient size for that item (although other criteria may also be applied to store the item on a larger shelf).

In some implementations, the loading coordination engine **804** may assign items to available locations based on the position of the delivery of the items in the sequence of deliveries. For example, the items may be assigned to depths or positions in a shelf on the mobile cart **116** in a reverse order of the sequence of deliveries. For example, the last-delivered items may be assigned to the back of a mobile cart **116** (e.g., on a given shelf) first, such that a front-most item on a given shelf would be retrieved from the shelf at delivery before items behind it on the shelf are retrieved during their respective deliveries.

In some implementations, the loading coordination engine **804** may use some, all, or different criteria to those described for sorting and assigning items to available locations. The methods for sorting and assigning may be performed in the order described or in another order. Further, it should be understood that other methods of sorting and assigning the items to locations in the delivery vehicle **104** may be used without departing from the scope of this disclosure and that other methods are possible and contemplated herein.

As an example, a set of items assigned to a delivery vehicle **104** (e.g., a particular route serviced by the delivery vehicle **104**) may be divided among the mobile carts **116** associated with the delivery vehicle **104**. The items may be sorted into groups based on delivery door, the items in the groups may be sorted into sub-groups based on size class of the items, and the items in sub-group may be sorted in a reverse order of delivery to place first delivered items at the front of shelves of the mobile cart **116** and later deliver items deeper in the shelves.

In some implementations, the items may be assigned one at a time to available locations in the delivery vehicle **104** using some, all, or different criteria than described above. For instance, items may be assigned one at a time if the sequence of deliveries or all items assigned to the mobile cart **116** are not yet known to the loading coordination engine **804** when assignment begins. For example, the loading coordination engine **804** may receive attributes of the item, such as the dimensions, delivery door, and delivery destination of the item, and, in response, the loading coordination engine **804** may assign the item to an available location on the mobile cart **116** and/or in the delivery vehicle **104 105** and instruct the AGV **102** to place the item at the assigned location, as described below.

In some implementations, the loading coordination engine **804** may use the data of those items already assigned to the delivery vehicle **104** to assign subsequent items to locations in the delivery vehicle **104**. For example, the loading coordination engine **804** may assign an item to the smallest available location on the mobile cart **116** that would fit the item. The item may be assigned to a location in front of a previously assigned item with a later delivery based on the sequence of deliveries. The item may be assigned to a back of a new section of a mobile cart **116** if no item with a later delivery is assigned. In some implementations, the loading coordination engine **804** may assign items to available locations beginning near to the delivery door for the deliveries of the items and moving away from the delivery door, although other implementations are possible. It should be understood that other sorting criteria are also possible and contemplated herein. In some implementations, this, or a similar, process may be repeated for subsequent items assigned by the loading coordination engine **804**.

At **712**, the loading coordination engine **804** may put the items in the set of items at the determined storage locations on the mobile cart **116** using the cart filling AGV **102***a*. For example, the loading coordination engine **804** may instruct a cart filling AGV **102***a* to transport the item to an assigned location and place the item at the assigned location, such as is described above in reference to FIG. **6**A.

FIG. **8** is a block diagram of an example loading coordination system **800** and data communication flow for automated loading of mobile carts **116** and delivery vehicles **104** using AGVs **102**. The system **800** may include a loading coordination server **802**, one or more AGVs **102**, one or more delivery vehicles **104**, a database **820**, and/or warehouse equipment **810**.

The components of the system **800** may be coupled to exchange data via wireless and/or wired data connections. The connections may be made via direct data connections and/or a computer network. The computer network may comprise any number of networks and/or types of networks, such as wide area networks, local area networks, virtual private networks, cellular networks, close or micro proximity networks (e.g., Bluetooth™ etc.), etc.

The loading coordination server **802** may, in some implementations, include one or more hardware and/or virtual servers programmed to perform the operations, acts, and/or functionality described herein. The components of the loading coordination server **802** may comprise software routines storable in one or more non-transitory memory devices and executable by one or more computer processors of the loading coordination server **802** to carry out the operations, acts, and/or functionality described herein. In further implementations, these routines, or a portion thereof, may be embodied in electrical hardware that is operable to carry out the operations, acts, and/or functionality described herein.

In some implementations, the loading coordination server **802**, or elements thereof, may be integrated with or communicatively coupled with a plurality of AGVs **102**. The loading coordination server **802** may include hardware and software configured to dispatch the AGVs **102**, and is coupled for communication the other components of the system **800** to receive and provide data. In some instances, the loading coordination server **802** may calculate a route to execute tasks considering traffic and resources. In some cases it adjusts the route or the task in order to keep the route optimum. In some implementations, the loading coordination server **802** may generate a schedule that defines the route and other operations for AGVs **102**, as described herein. For instance, the loading coordination server **802** may instruct AGVs **102** to navigate within a distribution facility, loading bay **106**, or delivery vehicle **104** according to the schedule. The schedule of a plurality of the AGVs **102** may be coordinated such that an optimal flow can be achieved.

The loading coordination engine **804** may comprise software routines storable in one or more non-transitory memory devices and executable by one or more computer processors to carry out the operations, acts, and/or functionality described herein. In further implementations, these routines, or a portion thereof, may be embodied in electrical hardware that is operable to carry out the operations, acts, and/or functionality described herein. Instances of the loading coordination engine **804***a*, **804***b*, . . . **804***n* may be executed by one or more of the components of the system **800**. The loading coordination engine **804** may be operable on the loading coordination server **802** (or another component of the system **800**) and communicatively coupled to receive data from and transmit data to other components of the system **800**, as described elsewhere herein. In some implementations, the loading coordination engine **804** may be configured to store, retrieve, and/or maintain data in the database **820**. In some implementations, the components, features, or functionality of the loading coordination engine **804** may be distributed among two or more components of the system **800**, for example.

The database **820** is an information source for storing and providing access to data. The data stored by the database **820** may be organized and queried using various criteria including any type of data stored by it. The database **820** may include data tables, databases, or other organized collections of data. Examples of the types of data stored by the database **820** may include, but are not limited to map data **822**, AGV data **828**, location assignment data **824**, order data **826**, item data **830**, vehicle data **832**, cart data **834**, etc. In some instances, the database **820** may also include conveyor system attributes, delivery destination attributes, sensor data, etc.

The database **820** may be included in the loading coordination server **802**, or in another computing system and/or storage system distinct from but coupled to or accessible by components of the system **800** to store, retrieve, or maintain data in the database **820**. In some implementations, the database **820** may be stored in a data store **908**, as described in reference to FIG. **9**. The database **820** can include one or more non-transitory computer-readable mediums for storing the data. In some implementations, the database **820** may store data associated with a database management system (DBMS) operable on a computing system. For example, the DBMS could include a structured query language (SQL) DBMS, a NoSQL DMBS, various combinations thereof, etc. In some instances, the DBMS may store data in multi-dimensional tables comprised of rows and columns, and manipulate, e.g., insert, query, update and/or delete, rows of data using programmatic operations.

The map data **822** may include data reflecting the 2 or 3 dimensional layout of zones, such as a facility, loading area, loading bay **106**, cart loading zone **132**, and/or delivery vehicle **104**, for example. In some instances, the map data **822** may include geographic map data, such as delivery areas and routes for delivery vehicles **104**. The map data **822** may include data about guidance system markers, such as unique identification codes of the markers and positions of the markers in the layout of the facility or AGV **102** operating environment, loading bay **106**, or delivery vehicle **104**.

The location assignment data **824** may include data representing available locations on a mobile cart **116** and/or a delivery vehicle **104** that may be assigned to items, such as what locations are available, the dimensions, capacities, 2 or 3 dimensional locations, etc., for example. The location assignment data may also include shelf specific information, such as the height, width, depth, weight capacity, shelf identifier, or other information about shelves on a mobile cart **116** or other location, although this information may be alternatively or additionally stored in cart data **834**. In some instances, the location assignment data **824** may also include whether and which items are assigned to and/or currently stored in the locations in a particular delivery vehicle **104**.

The order data **826** may include data about orders, the quantity and identity of items in orders, delivery destination (e.g., a shipping address) information for orders, customer account information, order priority, progress of order fulfillment, number of cartons in an order, etc.

The AGV **102** data **828** may describe the state of an AGV **102** (operational state, health, location, battery life, storage capacity, items being carried, etc.), whether and to which delivery vehicle **104** it is assigned, type of AGV **102**, components of AGV **102**, etc.

Item data **830** may describe unique identifiers for items, the location of the items, other attributes of the item (e.g., size, description, weight, quantity of items in a package, color, etc.), item inventory, mapping of items to locations in mobile carts **116**, item label or marker information, etc.

Vehicle data **832** may represent identification codes identifying specific delivery vehicles **104**; routes, items, AGVs **102** associated with delivery vehicles **104**, available locations, door docks **110**, etc. In some implementations, the vehicle data **832** may include attributes of the delivery vehicle **104**, such as its location, acceleration, number and configuration of doors, placement of cart lock mechanism (s), number and configuration of shelves or other storage locations in the delivery vehicle **104**, etc.

Cart data **832** may represent identification codes identifying specific mobile carts **116**, items associated with mobile carts **116**, available or assigned locations in mobile carts **116**, or other information about mobile carts **116**, such as their configuration, location, association with AGVs **102** or delivery vehicles **104**, shelf heights, weight capacities, etc.

An AGV **102**A . . . **102**N is an automated guided vehicle or robot that may be configured to autonomously transport items, as described in detail above in reference to FIGS. **1-3**. An AGV **102** may include a computing system (e.g., as in the example provided in FIG. **9**) with communication and processing capabilities. For example, the AGV **102** may run the loading coordination engine **804** or a component thereof. In some implementations, AGVs **102** may be differentiated into different types having varying duties, such as the cart filling AGV **102***a* and cart loading AGV **102***b* described above.

A delivery vehicle **104**A . . . **104**N may include a computing system that may communicate with other components of the loading coordination system **800** and may, in some instances, perform some operations described in reference to the loading coordination engine **804**. For example, a computing system of a delivery vehicle **104** may include the loading coordination engine **804** or a component thereof. In some implementations, the computing system of the delivery vehicle **104** may transmit information to an AGV **102** associated with the delivery vehicle **104**, as described above.

The loading coordination server **802** may be coupled with equipment **810**, such as a conveyor mechanism **108** (e.g., conveyor controls, conveyor scanners, conveyors, automated induction equipment, other warehouse equipment, etc.), described herein.

FIG. **9** is a block diagram of an example computing system **900**. This computing system **900** may represent the computer architecture of loading coordination server **802**, AGV **102**, or delivery vehicle **104**, as depicted in FIG. **8**, and may include different components depending on the implementation being represented.

As depicted in FIG. **9**, the computing system **900** may include a loading coordination engine **804**, depending on the configuration. In some implementations, the computing system **900** may store and/or operate other software that may be configured to interact with the loading coordination engine **804** via a communication unit **902**.

The loading coordination engine **804** may include software including logic executable by the processor **904** to perform its respective operations described herein, although in further implementations the loading coordination engine **804** may be implemented in hardware (one or more application specific integrated circuits (ASICs) coupled to the bus **910** for cooperation and communication with the other components of the system **900**; sets of instructions stored in one or more discrete memory devices (e.g., a PROM, FPROM, ROM) that are coupled to the bus **910** for cooperation and communication with the other components of the system **900**; a combination thereof; etc.).

As depicted, the computing system **900** may include a processor **904**, a memory **906**, a communication unit **902**, an output device **916**, an input device **914**, and data store(s) **908**, which may be communicatively coupled by a communication bus **910**. The computing system **900** depicted in FIG. **9** is provided by way of example and it should be understood that it may take other forms and include additional or fewer components without departing from the scope of the present disclosure. For instance, various components of the computing system(s) may be coupled for communication using a variety of communication protocols and/or technologies including, for instance, communication buses, software communication mechanisms, computer networks, etc. While not shown, the computing system **900** may include various operating systems, sensors, additional processors, and other physical configurations. Although, for purposes of clarity, FIG. **9** only shows a single processor **904**, memory **906**, communication unit **902**, etc., it should be understood that the computing system **900** may include a plurality of one or more of these components.

The processor **904** may execute software instructions by performing various input, logical, and/or mathematical operations. The processor **904** may have various computing architectures to process data signals including, for example, a complex instruction set computer (CISC) architecture, a reduced instruction set computer (RISC) architecture, and/or an architecture implementing a combination of instruction sets. The processor **904** may be physical and/or virtual, and may include a single core or plurality of processing units and/or cores. In some implementations, the processor **904** may be capable of generating and providing electronic display signals to a display device, supporting the display of images, capturing and transmitting images, performing complex tasks including various types of feature extraction and sampling, etc. In some implementations, the processor **904** may be coupled to the memory **906** via the bus **910** to access data and instructions therefrom and store data therein. The bus **910** may couple the processor **904** to the other components of the computing system **900** including, for example, the memory **906**, the communication unit **902**, the input device **914**, the output device **916**, and the data store(s) **908**.

The memory **906** may store and provide access to data to the other components of the computing system **900**. The memory **906** may be included in a single computing device or a plurality of computing devices. In some implementations, the memory **906** may store instructions and/or data that may be executed by the processor **904**. For example, the memory **906** may store a loading coordination engine **804** and its respective components, depending on the configuration. The memory **906** is also capable of storing other instructions and data, including, for example, an operating system, hardware drivers, other software applications, databases, etc. The memory **906** may be coupled to the bus **910** for communication with the processor **904** and the other components of computing system **900**.

The memory **906** may include a non-transitory computer-usable (e.g., readable, writeable, etc.) medium, which can be any non-transitory apparatus or device that can contain, store, communicate, propagate or transport instructions, data, computer programs, software, code, routines, etc., for processing by or in connection with the processor **904**. In some implementations, the memory **906** may include one or more of volatile memory and non-volatile memory (e.g., RAM, ROM, hard disk, optical disk, etc.). It should be understood that the memory **906** may be a single device or may include multiple types of devices and configurations.

The bus **910** can include a communication bus for transferring data between components of a computing system or between computing systems, a network bus system including a computer or portions thereof, a processor mesh, a combination thereof, etc. In some implementations, the various components operating on the computing system **900** (operating systems, device drivers, etc.) may cooperate and communicate via a communication mechanism included in or implemented in association with the bus **910**. The software communication mechanism can include and/or facilitate, for example, inter-method communication, local function or procedure calls, remote procedure calls, an object broker (e.g., CORBA), direct socket communication (e.g., TCP/IP sockets) among software modules, UDP broadcasts and receipts, HTTP connections, etc. Further, any or all of the communication could be secure (e.g., SSH, HTTPS, etc.).

The communication unit **902** may include one or more interface devices (I/F) for wired and wireless connectivity among the components of the system **800**. For instance, the communication unit **902** may include various types known connectivity and interface options. The communication unit **902** may be coupled to the other components of the computing system **900** via the bus **910**. The communication unit **902** may be electronically communicatively coupled to a network or other components of the system **800** (e.g., by wire, wirelessly, etc.). In some implementations, the communication unit **902** can link the processor **904** to a computer network, which may in turn be coupled to other processing systems. The communication unit **902** can provide other connections to other entities of the system **800** using various standard communication protocols.

The input device **914** may include any device for inputting information into the computing system **900**. In some implementations, the input device **914** may include one or more peripheral devices. For example, the input device **914** may include a keyboard, a pointing device, microphone, an image/video capture device (e.g., camera), a touch-screen display integrated with the output device **916**, etc.

The output device **916** may be any device capable of outputting information from the computing system **900**. The output device **916** may include one or more of a display (LCD, OLED, etc.), a printer, a haptic device, audio reproduction device, touch-screen display, etc. In some implementations, the output device is a display which may display electronic images and data output by the computing system **900** for presentation to a user. In some implementations, the computing system **900** may include a graphics adapter (not shown) for rendering and outputting the images and data for presentation on output device **916**. The graphics adapter (not shown) may be a separate processing device including a separate processor and memory (not shown) or may be integrated with the processor **904** and memory **906**.

The data store(s) are information source(s) for storing and providing access to data, such as the database **820** and/or data described in reference to the database **820**. The data stored by the data store(s) **908** may organized and queried using various criteria including any type of data stored by them, such as the data described in reference to the database **820** in FIG. **8**. The data store(s) **908** may include file systems, data tables, documents, databases, or other organized collections of data.

The data store(s) **908** may be included in the computing system **900** or in another computing system and/or storage system distinct from but coupled to or accessible by the computing system **900**. The data store(s) **908** can include one or more non-transitory computer-readable mediums for storing the data. In some implementations, the data store(s) **908** may be incorporated with the memory **906** or may be distinct therefrom. In some implementations, the data store (s) **908** may store data associated with a database management system (DBMS) operable on the computing system **900**. For example, the DBMS could include a structured query language (SQL) DBMS, a NoSQL DMBS, various combinations thereof, etc. In some instances, the DBMS may store data in multi-dimensional tables comprised of rows and columns, and manipulate, e.g., insert, query, update and/or delete, rows of data using programmatic operations.

It should be noted that the components described herein may be further delineated or changed without departing from the techniques described herein. For example, the processes described throughout this disclosure may be performed by fewer, additional, or different components.

It should be understood that the methods described herein are provided by way of example, and that variations and combinations of these methods, as well as other methods, are contemplated. For example, in some implementations, at least a portion of one or more of the methods represent various segments of one or more larger methods and may be concatenated or various steps of these methods may be combined to produce other methods which are encompassed by the present disclosure. Additionally, it should be understood that various operations in the methods are iterative, and thus repeated as many times as necessary generate the results described herein. Further the ordering of the operations in the methods is provided by way of example and it should be understood that various operations may occur earlier and/or later in the method without departing from the scope thereof.

In the above description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it should be understood that the technology described herein can be practiced without these specific details in various cases. Further, various systems, devices, and structures are shown in block diagram form in order to avoid obscuring the description. For instance, various implementations are described as having particular hardware, software, and user interfaces. However, the present disclosure applies to any type of computing device that can receive data and commands, and to any peripheral devices providing services.

In some instances, various implementations may be presented herein in terms of algorithms and symbolic representations of operations on data bits within a computer memory. An algorithm is here, and generally, conceived to be a self-consistent set of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

It should be borne in mind, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout this disclosure, discussions utilizing terms such as "processing," "computing," "calculating," "determining," "displaying," or the like, refer to the action and methods of a computer system that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

A data processing system suitable for storing and/or executing program code, such as the computing system and/or devices discussed herein, may include at least one processor coupled directly or indirectly to memory elements through a system bus. The memory elements can include local memory employed during actual execution of the program code, bulk storage, and cache memories that provide temporary storage of at least some program code in order to reduce the number of times code must be retrieved from bulk storage during execution. Input or I/O devices can be coupled to the system either directly or through intervening I/O controllers. The data processing system may include an apparatus may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer.

The foregoing description has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the specification to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the disclosure be limited not by this detailed description, but rather by the claims of this application. As will be understood by those familiar with the art, the specification may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. Likewise, the particular naming and division of the modules, routines, features, attributes, methodologies and other aspects may not be mandatory or significant, and the mechanisms that implement the specification or its features may have different names, divisions, and/or formats.

Furthermore, the modules, routines, features, attributes, methodologies and other aspects of the disclosure can be implemented as software, hardware, firmware, or any combination of the foregoing. The technology can also take the form of a computer program product accessible from a computer-usable or computer-readable medium providing program code for use by or in connection with a computer or any instruction execution system. Wherever a component, an example of which is a module or engine, of the specification is implemented as software, the component can be implemented as a standalone program, as part of a larger program, as a plurality of separate programs, as a statically or dynamically linked library, as a kernel loadable module, as firmware, as resident software, as microcode, as a device driver, and/or in every and any other way known now or in the future. Additionally, the disclosure is in no way limited to implementation in any specific programming language, or for any specific operating system or environment. Accordingly, the disclosure is intended to be illustrative, but not limiting, of the scope of the subject matter set forth in the following claims.

What is claimed is:

1. A method comprising:

assigning, by a loading coordination engine, a location on a mobile cart to an item;

generating, by the loading coordination engine, a task list including a first instruction to a first automated guided vehicle ("AGV") to position the item on the mobile cart based on the assigned location and a second instruction to a second AGV to transport the mobile cart into a delivery vehicle, the second AGV being adapted to move multiple mobile carts into the delivery vehicle, each of the mobile carts having multiple shelves adapted to hold items, the delivery vehicle being adapted to simultaneously hold the multiple mobile carts;

instructing, by the loading coordination engine, a controller of the first AGV carrying the item to navigate the first AGV from an item loading area to a point proximate to the assigned location on the mobile cart;

responsive to determining that the first AGV has reached the point proximate to the assigned location on the mobile cart, instructing, by the loading coordination engine, the controller of the first AGV to place the item at the assigned location based on the task list; and

instructing, by the loading coordination engine, a controller of the second AGV coupled with the mobile cart to navigate the mobile cart from a cart loading zone into a securable position in the delivery vehicle with a previously-placed mobile cart based on the task list.

2. The method of claim **1**, further comprising:

generating, by the loading coordination engine, a delivery task;

assigning, by the loading coordination engine; the delivery vehicle to a door dock at a loading facility based on the delivery task; and

instructing, by the loading coordination engine, the second AGV coupled with the mobile cart to navigate from the delivery vehicle to the cart loading zone associated with the door dock, the cart loading zone being determined based on the assignment of the door dock.

3. The method of claim **2**, further comprising:

receiving, by the loading coordination engine, a notification message indicating arrival of the delivery vehicle at the door dock;

transmitting, by the loading coordination engine, an instruction to release a cart lock, the cart lock configured to secure the mobile cart to the delivery vehicle;

instructing, by the loading coordination engine, the controller of the second AGV to couple the second AGV with the mobile cart; and

instructing, by the loading coordination engine, the controller of the second AGV to navigate the second AGV from the delivery vehicle to the cart loading zone.

4. The method of claim **1**, wherein instructing the controller of the first AGV carrying the item to navigate the first AGV from an item loading area to the point proximate to the assigned location on the mobile cart includes

instructing, by the loading coordination engine, the controller of the first AGV to navigate the first AGV to the item loading area,

instructing, by the loading coordination engine, the controller of the first AGV to retrieve, by the first AGV, the item from the item loading area,

determining, by the loading coordination engine, the point proximate to the assigned location on the mobile cart based on a location of the mobile cart, the assigned location, and a range of motion of an item handling mechanism of the first AGV, and

instructing, by the loading coordination engine, the controller of the first AGV to navigate the first AGV to the point proximate to the assigned location on the mobile cart in the cart loading zone.

5. The method of claim **1**, wherein instructing the controller of the first AGV to place the item and the assigned location based on the task list includes instructing the controller of the first AGV to articulate an item handling mechanism of the first AGV to a height matching a shelf of the mobile cart at which the assigned location is located, and transfer the item from the item handling mechanism to the shelf at the assigned location.

6. The method of claim **1**, wherein instructing the controller of the second AGV coupled with the mobile cart to navigate the mobile cart from the cart loading zone into the securable position in the delivery vehicle based on the task list includes

instructing the controller of the second AGV to navigate the second AGV to the cart loading zone,

instructing the controller of the second AGV to couple the second AGV with the mobile cart in the cart loading zone, and

instructing the controller of the second AGV to apply motive force to the mobile cart by the second AGV using a guidance system of the second AGV to transport the mobile cart into the delivery vehicle.

7. The method of claim **1**, further comprising: responsive to determining that the mobile cart has arrived at the securable position in the delivery vehicle, instructing, by the loading coordination engine, the controller of the second AGV to secure the mobile cart to the delivery vehicle by actuating a cart lock.

8. The method of claim **1**, wherein the first AGV includes a first drive unit that provides motive force to the first AGV, a first guidance system that locates the first AGV in an operating environment, and an item handling mechanism adapted to move items.

9. The method of claim **8**, wherein the second AGV includes a second drive unit that provides motive force to the second AGV, a second guidance system that locates the second AGV in the operating environment, and a cart coupling mechanism that couples the second AGV with the mobile cart.

10. The method of claim **1**, further comprising:

receiving data describing a label captured by a scanner communicatively coupled with the loading coordination engine;

determining, by the loading coordination engine, a delivery destination of the item based on the data describing the label; and

assigning, by the loading coordination engine, the item to the location on the mobile cart based on the delivery destination of the item.

11. The method of claim **1**, comprising:

assigning, by the loading coordination engine, the item to a door dock associated with the delivery vehicle based on a delivery destination of the item; and

instructing, by the loading coordination engine, a conveyor mechanism to transport the item to the door dock associated with the delivery vehicle.

12. The method of claim **1**, wherein assigning the item to the location on the mobile cart includes

determining one or more measurements of the item,

determining one or more measurements of available storage locations on the mobile cart,

determining a position of a delivery of the item in a sequence of deliveries of a set of items assigned to the delivery vehicle, and

determining the assigned location of the item based on the one or more measurements of the item, the one or more measurements of the available storage locations on the mobile cart, and the position of the delivery of the item in the sequence of deliveries.

13. A system comprising:

a first automated guided vehicle ("AGV");

a second AGV;

a delivery vehicle adapted to simultaneously hold multiple mobile carts, each of the multiple mobile carts having multiple shelves adapted to hold items; and

a computing system including one or more processors and a memory storing instructions that, when executed by the one or more processors, cause the system to:

assign a location on a mobile cart to an item;

generate a task list including a first instruction to the first AGV to position the item on the mobile cart based on the assigned location and a second instruction to the second AGV to transport the mobile cart into the delivery vehicle, the task list including moving the multiple mobile carts into the delivery vehicle by the second AGV;

transport, by the first AGV, the item from an item loading area to a point proximate to the assigned location on the mobile cart;

place, by the first AGV, the item at the assigned location based on the task list; and

transport, by the second AGV, the mobile cart from a cart loading zone into a securable position in the delivery vehicle based on the task list.

14. The system of claim **13**, wherein the instructions further cause the system to

generate a delivery task,

assign the delivery vehicle to a door dock at a loading facility based on the delivery task, and

transport the mobile cart from the delivery vehicle to the cart loading zone associated with the door dock using the second AGV, the cart loading zone being determined based on the assignment of the door dock.

15. The system of claim **14**, wherein the instructions further cause the system to

receive a notification message indicating arrival of the delivery vehicle at the door dock,

transmit an instruction to release a cart lock, the cart lock configured to secure the mobile cart to the delivery vehicle,

couple the second AGV with the mobile cart, and

transport the mobile cart from the delivery vehicle to the cart loading zone using the second AGV.

16. The system of claim **13**, wherein transporting, by the first AGV, the item from the item loading area to the point proximate to the assigned location on the mobile cart includes

navigating the first AGV to the item loading area,

retrieving the item from the item loading area by the first AGV,

determining the point proximate to the assigned location on the mobile cart based on a location of the mobile cart, the assigned location, and a range of motion of an item handling mechanism of the first AGV, and

navigating the first AGV to the point proximate to the assigned location on the mobile cart in the cart loading zone.

17. The system of claim **13**, wherein placing, by the first AGV, the item at the assigned location based on the task list includes articulating an item handling mechanism of the first AGV to a height matching a shelf of the mobile cart at which the assigned location is located, and transferring the item from the item handling mechanism to the shelf at the assigned location.

18. The system of claim **13**, wherein transporting, by the second AGV, the mobile cart from the cart loading zone into the delivery vehicle based on the task list includes

navigating the second AGV to the cart loading zone,

coupling the second AGV with the mobile cart in the cart loading zone, and

navigating the second AGV with the mobile cart using a guidance system of the second AGV including applying motive force to the mobile cart by the second AGV to transport the mobile cart into the delivery vehicle.

19. The system of claim **13**, further comprising responsive to determining that the mobile cart has arrived at the securable position in the delivery vehicle, securing the mobile cart to the delivery vehicle by actuating a cart lock adapted to secure the mobile cart to the delivery vehicle.

20. The system of claim **13**, wherein the first AGV includes a first drive unit that provides motive force to the first AGV, a first guidance system that locates the first AGV in an operating environment, and an item handling mechanism adapted to move items.

21. The system of claim **20**, wherein the second AGV includes a second drive unit that provides motive force to the second AGV, a second guidance system that locates the second AGV in the operating environment, and a cart coupling mechanism that couples the second AGV with the mobile cart.

22. The system of claim **13**, wherein the instructions further cause the system to

capture a label of the item using a scanner communicatively coupled with the computing system,

determine a delivery destination based on the captured label on the item, and

assign the item to the location on the mobile cart based on the delivery destination of the item.

23. The system of claim **13**, wherein the instructions further cause the system to

assign the item to a door dock associated with the delivery vehicle based on a delivery destination of the item, and

instruct a conveyor mechanism to transport the item to the door dock associated with the delivery vehicle.

24. The system of claim **13**, wherein assigning the item to the location on the mobile cart includes

determining one or more measurements of the item,

determining one or more measurements of available storage locations on the mobile cart,

determining a position of a delivery of the item in a sequence of deliveries of a set of items assigned to the delivery vehicle, and

determining the assigned location of the item based on the one or more measurements of the item, the one or more measurements of the available storage locations on the mobile cart, and the position of the delivery of the item in the sequence of deliveries.

25. One or more automated guided vehicles ("AGVs") comprising:

a body;

a drive unit coupled with the body and providing motive force to the body;

a guidance system coupled with a controller, the guidance system locating the one or more AGVs in an operating environment;

an item handling mechanism coupled with the body and the controller, the item handling mechanism adapted to move an item; and

the controller coupled with the drive unit, the guidance system, and the item handling mechanism, the controller performing operations including:

receiving an instruction from a computing system, the instruction identifying a location on a mobile cart in a cart loading zone, the location being assigned to the item;

transporting, by the one or more AGVs, the item from an item loading area to a point proximate to the assigned location on the mobile cart, transporting including navigating using the drive unit and the guidance system;

placing the item at the assigned location using the item handling mechanism of the one or more AGVs; and

transporting, by the one or more AGVs, the mobile cart from the cart loading zone into a delivery vehicle based on the item being placed at the assigned location, the one or more AGVs being adapted to move multiple mobile carts into the delivery vehicle, each of the mobile carts having multiple shelves adapted to hold items, the delivery vehicle being adapted to simultaneously hold the multiple mobile carts.

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